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Surfaces: More than just roughness

Regardless of the end-use application, it would be wise to consider the totality of a surface (i.e. its texture) rather than just a simplistic roughness measurement such as Ra.

While surface quality is often simplified to refer only to surface roughness, surface texture is the more complete concept that should be considered for many engineered component applications.

REM and many others have written and presented the importance of surface roughness for gear and other power transfer systems. My colleagues and I have presented the differences between machined (in this case referring primarily to ground) surfaces and isotropic surfaces [1] and the impact that the difference between these two surface textures has for gear and other applications (see Figures 1 and 2). Further, we have expounded on the need to measure surface roughness correctly [2], to specify roughness call-outs properly on a drawing [3], to consider what surface roughness parameters you are using versus your gear surface forming technique [4], to properly calibrate a contact-based profilometer [5] [6], to consider what micron-size stylus tip you are using [7], impending changes to roughness measurements standards [8], and even the merits/challenges of optical vs. contact-based profilometry [9]. But we have not delved deeply, in any of these columns, into the broader concept of surface texture.

As the manufacturing community changes and evolves, there is always a need to reevaluate how one thinks about things. New technology introductions and maturations are common drivers for these types of reconsiderations, and the manner in which we think about and qualify surfaces is certainly not immune from this occurrence. Such has been the case at REM in recent years, as a result of our growing and broadening work in the metal additive manufacturing industry (AM). AM has a known challenge in regard to the correct manner in which to classify as-printed surfaces. Powder bed-based processes especially suffer from the fact that previously generated roughness measurement standards and parameters (such as Ra, Rz, etc.) were not conceived with granular surfaces in mind [10] (see Figures 3 and 4). As a result, we were driven to dive deeper into surface characterization and to advocate for the more holistic consideration of surface texture as opposed to just surface roughness.

But what is surface texture in a formal sense? Surface texture is a combination of a component's form, its surface waviness, and its surface roughness (see Figures 5 [11] and 6 [10]). Surface roughness measurements seek to filter out form and waviness, but these filters are "one size fits most". For many machined/ground surfaces, they are effective and can provide valuable insight into surface quality and derivatively into predictive gear performance calculations/design criteria. But these filters are not perfect, and non-standard surface textures such as AM surfaces (which are both extremely rough and wavy) or isotropic superfinished surfaces (which will have little to no roughness) may not be adequately quantified — thus, additional consideration to waviness or other parameters may be required. As such,

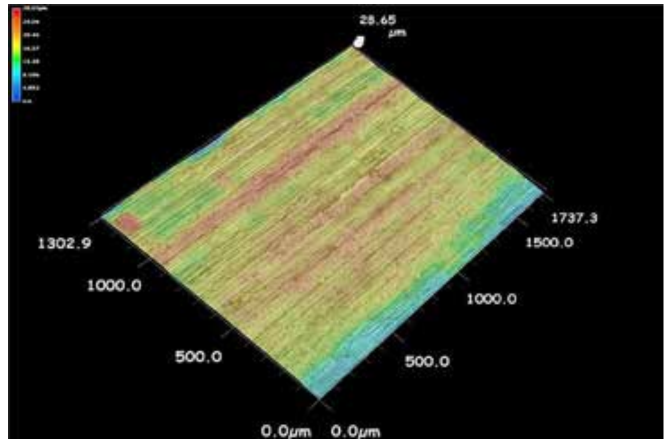

Figure 1: 3D digital micrograph of a ground surface.

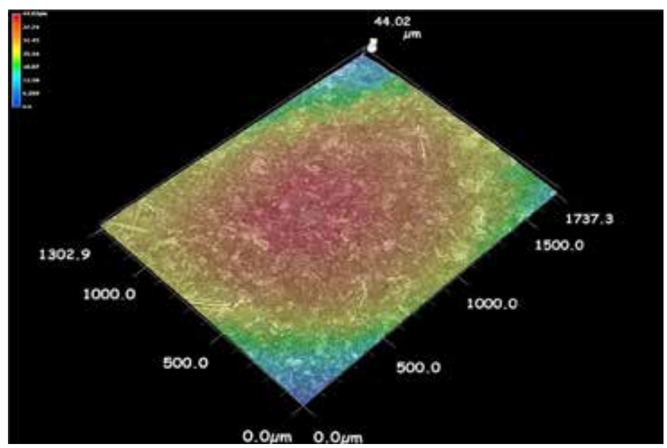

Figure 2: 3D digital micrograph of an isotropic superfinish.

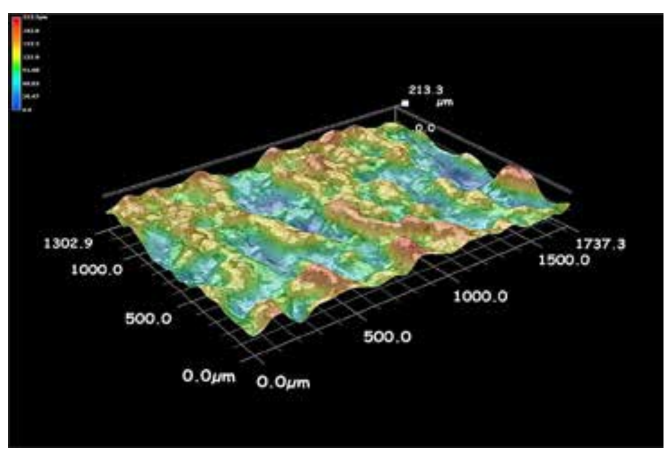

Figure 3: 3D digital micrograph of a granular surface.

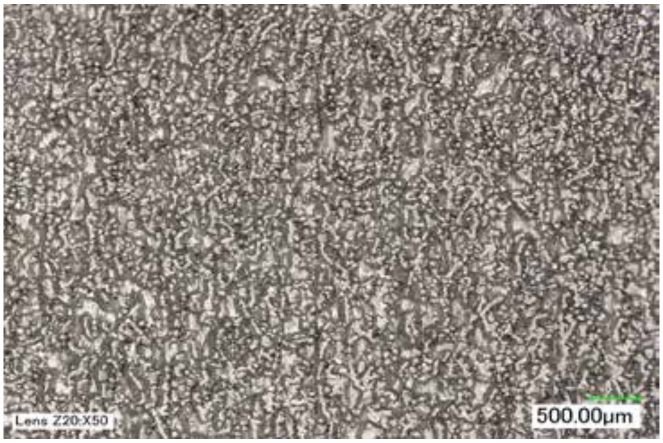

Figure 4: Digital micrograph of a granular surface.

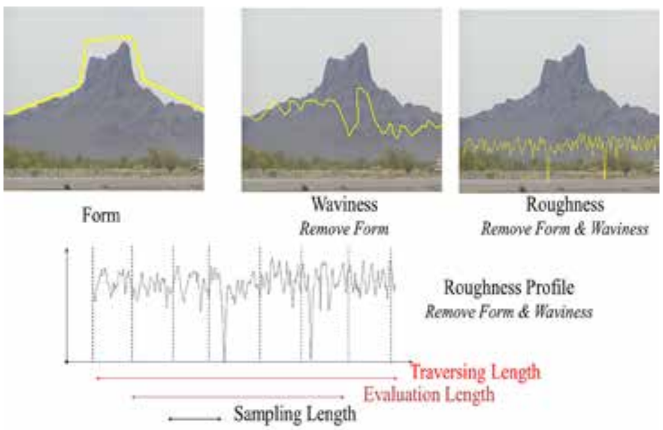

Figure 5: Illustration of form, waviness, and roughness as components of surface texture relative to a 2D contact-based surface roughness measurement.

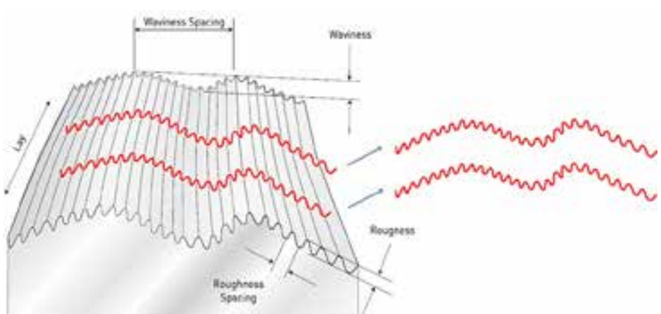

Figure 6: Illustration of waviness and roughness depicting the filtering of waviness.

all three features should be considered when evaluating a surface relative to both how it will be used and how it should be classified.

It is unfortunately a not uncommon occurrence for roughness measurements of a gear flank to be taken improperly, parallel to the machining marks on the component. In so doing, both the roughness and waviness of the surface will be improperly quantified relative to the actual functional surface texture of the gear flank relative to the known rolling-sliding motion of the actual gear system. But, you may ask, assuming I can avoid improper contact-based profilometry techniques, or if I am using optical profilometry, why should I care about surface texture for a gear flank surface? Well, while form deviations for gears are identified via specialized gear testing machines and/or CMMs, waviness can still influence your surface roughness measurements leading to higher roughness values. While roughness can be removed via processes such as isotropic superfinishing, gear flank waviness can be a more challenging defect to remove depending on a range of factors including material removal tolerances and gear pitch. Further, as has been discussed in the past [4], many surfaces can potentially have the same roughness (Ra or other) value, but if surface texture is considered, even qualitatively, there may be significant differences in surface type/quality. The periodic or parallel directionality of the surface texture on a machined or ground surface is known differently in operation relative to various gear failure modes as compared to an isotropically superfinished surface even if measured roughness values appear to be equivalent due to the known differences in surface texture [12] [13].

These comments are not intended to suggest that there is a single, optimal surface for all gears or more broadly, all metal-to-metal contact, power transfer components. Many gear applications can function effectively with varying levels of roughness/waviness and even varying degrees of form deviations. Rather, it is simply important to consider the true nature of a component's surface relative to its intended use, direction of motion, operating requirements, etc. It is generally accepted that high-speed and/or highly-loaded gears will benefit from a low roughness, low waviness, isotropic surface texture, but other gear applications may not require this type of surface. Regardless of your end-use application, it would be wise to consider

the totality of a surface (i.e. its texture) rather than just a simplistic roughness measurement such as Ra.

REFERENCES

[1] Michaud, J. "Materials Matter: Gear Surfaces and Operational Performance." Gear Solutions, December 16, 2015, https://gearsolutions.com/departments/materials-matter-gear-surfaces-and-operational-performance/

[2] Michaud, M. "Materials Matter: Roughness Measurement of Precision Gear Teeth." Gear Solutions, January 19, 2016, https://gearsolutions.com/departments/materials-matter-roughness-measurement-of-precision-gear-teeth/

[3] Michaud, M. "Materials Matter: The Gear Drawing Roughness Specification." Gear Solutions, February 19, 2016, https://gearsolutions.com/departments/materials-matter-the-gear-drawing-roughness-specification/

[4] Bell, M. "Materials Matter: Comparing Surface Roughness Parameters." Gear Solutions, December 15, 2016, https://gearsolutions.com/departments/materials-matter-comparing-surface-roughness-parameters/

[5] Michaud, M. "Materials Matter: Roughness Measurement Tips: The Scratch Pad." Gear Solutions, January 15, 2020, https://gearsolutions.com/departments/materials-matter/roughness-measurement-tips-the-scratch-pad/

[6] Michaud, M. "Materials Matter: Roughness Measurement Tips: Calibration, The Razor Blade Test." Gear Solutions, February 15, 2020, https://gearsolutions.com/departments/materials-matter/roughness-measurement-tips-calibration-the-razor-blade-test/

[7] Michaud, M. "Materials Matter: Roughness Measurement Tips: 2 vs. 5 Micron." Gear Solutions, December 15, 2019, https://gearsolutions.com/departments/materials-matter/roughness-measurement-tips-2-vs-5-micron/

[8] Michaud, M. "Materials Matter: Roughness Measurement Tips: Optical vs. Contact Stylus Profilometry." Gear Solutions, May 15, 2020, https://gearsolutions.com/departments/materials-matter/changes-ahead-in-the-roughness-standards/

[9] Michaud, M. "Materials Matter: Roughness Measurement Tips: Optical vs. Contact Stylus Profilometry." Gear Solutions, April 15, 2020, https://gearsolutions.com/departments/materials-matter/roughness-measurement-optical-vs-contact-stylus-profilometry/

[10] Exploring Surface Texture: A Fundamental Guide to the Measurement of Surface Finish, 7th Ed., Taylor Hobson, 2014

[11] Borrowed/modified with permission from Michigan Metrology, LLC

[12] Graf, W. "Polish Grinding of Gears for Higher Transmission Efficiency." Gear Solutions, May 27, 2016, https://gearsolutions.com/features/polish-grinding-of-gears-for-higher-transmission-efficiency/

[13] Winkelmann, L., et al. "The Effect of Superfinishing on Gear Micropitting, Part II." AGMA 08FTM10

ABOUT THE AUTHOR

Justin Michaud is president and CEO of REM Surface Engineering, where he works closely with the research team, supports REM's government projects and awards, and focuses heavily on REM's surface finishing solutions for metal additive manufacturing applications. Michaud serves on the American Gear Manufacturers Association (AGMA) Emerging Technology Committee and is the chair to the 3D Printing sub-committee. He is an author of multiple technical papers on topics including additive manufacturing, isotropic superfinishing, gear failure modes, surface texture and measurement, high value gear repair, and the superfinishing of high hardness steels.