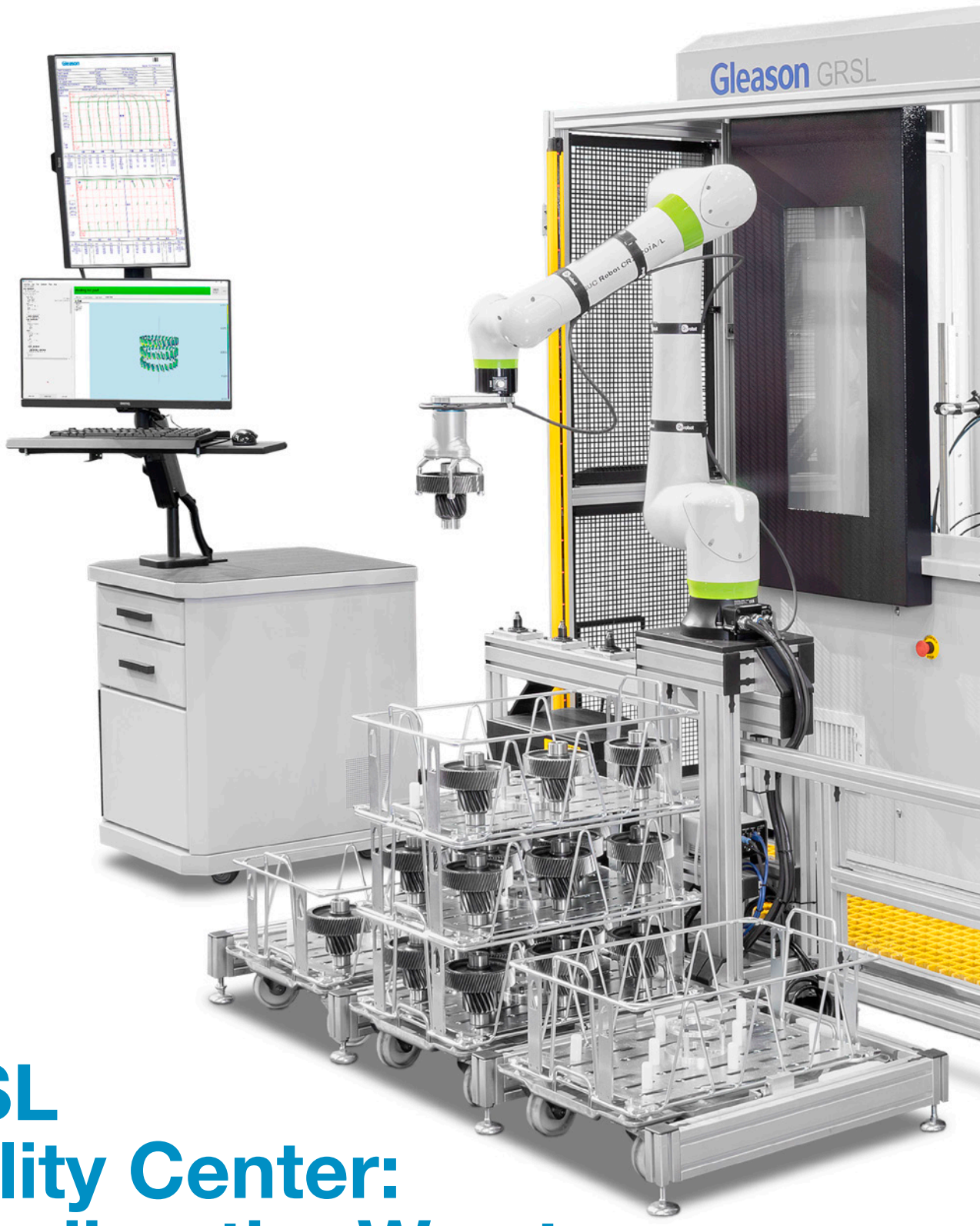

GRSL Quality Center: Speeding the Way to Quieter Gears

Gleason's GRSL Quality Center brings fast gear inspection to the shop floor for higher quality gears

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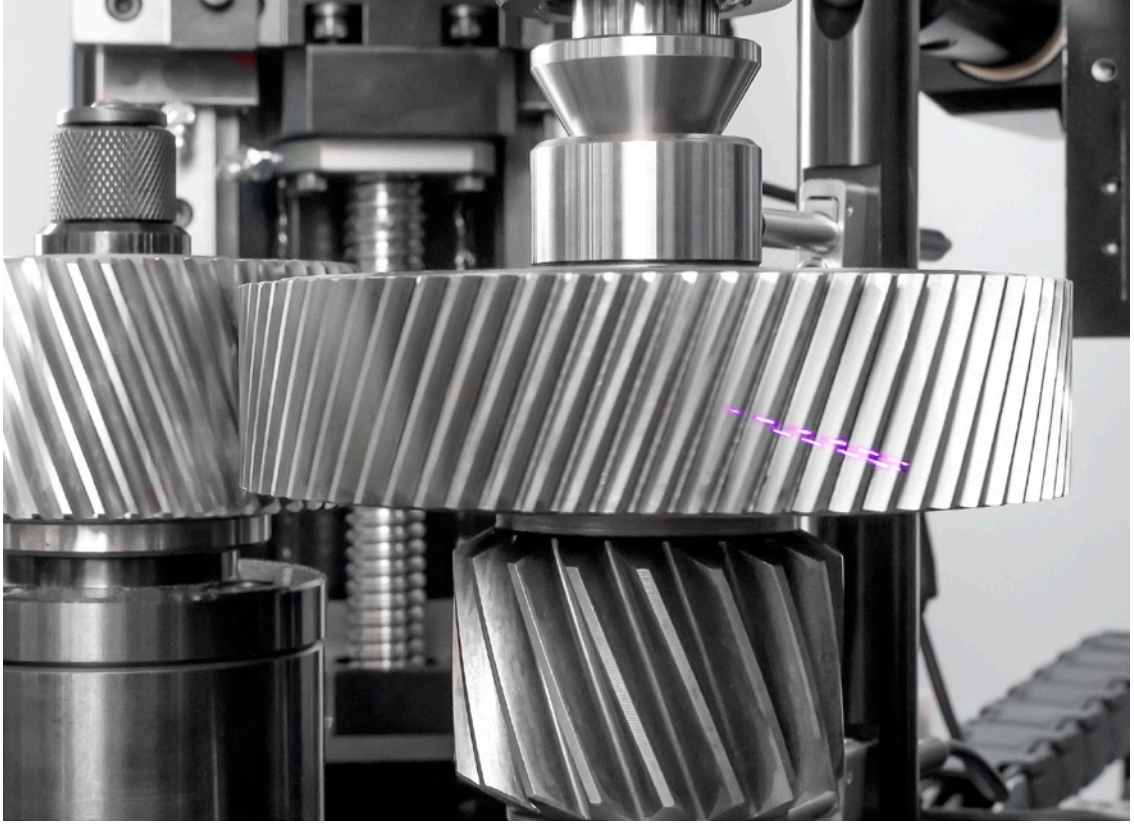

GRSL rolls multiple inspection methods into a single platform: optical inspection of profile, lead, and pitch; DOP and tooth thickness; double flank composite testing; and sophisticated in-process gear noise analysis.

The arrival of Gleason's Hard Finishing Cell (HFC) in 2018 represented a paradigm shift in the way automotive transmission gears and gears for e-drives, could be produced in high volumes. Now, for the first time, 100 percent inspection of every gear, and every gear tooth was possible in-process, without impacting the high speeds at which these gears need to be hard finished. Identifying, and correcting for, conditions that create unacceptable noise behavior in these gears, on the fly, was finally a reality too. Compare that to the approach gear manufacturers traditionally take. In a typical hard fine finishing operation like continuous generating grinding, it is not unusual to measure only one or two workpieces per dressing cycle or directly after the machine setup. Depending on the dressing cycle, the number of inspected parts corresponds to only about five percent of workpieces produced in total. However, to guarantee almost 100 percent reliability, statistical evaluation is instead used to validate the gears being produced. Typical measuring characteristics can be represented and statistically evaluated on a Gaussian bell curve. By deliberately narrowing down tolerances on the measured components, it is possible to guarantee compliance with the required drawing tolerances with a sufficiently high probability (typically > 99.99994 percent). This method is commonly used for machine and process capability studies and is globally recognized. The machine or process capability values c_{mk} and c_{pk}, frequently taken as a basis, are usually set above 1.67. Statistically, the reject rate is only 0.57 workpieces per 1 million manufactured workpieces, which means that only about 50 percent of the intended drawing tolerances are available as manufacturing tolerances. This situation is aggravated by the fact of increasing quality demands, especially with e-drive gears, due to NVH and other topics leading to increasingly tight tolerances. This high dependency on statistics poses a significant challenge to a growing number of gear manufacturers.

Another significant challenge is the long wait time between part removal for inspection and the actual availability of measured results. Part movement, waiting, and inspection time can easily amount to between 30 to 45 minutes depending on the inspection room capacity. After inspection, a decision must be made as to whether a correction of machine settings is necessary. The implementation of such corrections must be carried out by the machine operator, taking additional time—all while gears, good or bad, are continuously produced.

Gleason's HFC incorporated a remarkable new inspection solution to address both long-standing issues: the GRSL (Gear Rolling System with Integrated Laser Scanning), featuring a combination of double flank roll testing and laser scanning. GRSL rolled multiple inspection methods into a single platform—optical inspection of profile, lead, and pitch; DOP and tooth thickness; double flank composite testing; and sophisticated in-process gear noise analysis—all performed in just seconds, making it possible to inspect every gear without sacrificing precious cycle time.

GRSL Stands Alone

Fortunately, the many benefits of GRSL aren't simply confined to HFC application. With the arrival today of the stand-alone GRSL Quality Center any manufacturer can meet their 100 percent inspection requirements, while at the same time taking precious time out of the hard fine finishing and inspection of a wide range of high-precision cylindrical gears with low noise requirements. Furthermore, the GRSL Quality Center is 'shop hardened' and designed for installation right on the production

floor close to the machines producing parts for inspection. Now, with a single stand-alone GRSL, served by an integrated cobot loader, the manufacturer can eliminate the much more time-consuming, labor-intensive inspection process that typically includes multiple inspection machines (analytical inspection systems, roll testers, DOP gages), skilled operators, and transport between inspection stations. Instead, this single GRSL platform does it all, and in a fraction of the time: optical pitch, lead, and profile inspection for all teeth on a workpiece, as well as dual flank rolling testing including inspection for tooth flank damage, total dual flank working deviation and dual flank working error, functional runout, DOB measurement, average tooth thickness and more. Most significantly, the results of the inspection are available immediately and can be sent back to the production machine in a continuous closed loop so the necessary corrections can be made on the fly, without waiting many minutes, perhaps hours, for inspection results using traditional methods. By inspecting up to 100 percent of parts, manufacturers can monitor trends and apply preventive corrections before parts are even out of tolerance, helping to predict whether a workpiece could cause noise issues within the gearbox after its assembly.

Noise Analysis

With the rise of EVs, reducing or even eliminating gear noise is now uppermost in the minds of gear designers. The work is ongoing, but there's no single, simple solution. Gear noise can have many causes. When gear noise issues occur, producers often focus solely on the manufacturing process. However, this is not always the root cause. For a gearing system to function quietly, it must first be designed properly according to the load characteristics that will appear later in the real gearbox. Gear design that assumes ideal conditions is no longer an adequate predictor of whether that gear will operate quietly in the real world. A much better approach is to employ loaded tooth contact analysis that considers the true gear geometry, realistic loads, and deformations of the gearbox elements. Even perfectly designed gears are subject to manufacturing errors that can also produce the gear noise condition called 'ghost noise'. Hence, it is important to have analysis tools capable of detecting potential noise issues and distinguishing between manufacturing and design root causes. At this, the GRSL Quality Center excels.

In comparison to traditional methods of inspection, and their use in the search for the root causes of noise—whether design or manufacturing-related—GRSL is truly light years ahead. Laser scanning provides comprehensive data volumes that go well beyond standard gear characteristics such as profile, lead, pitch, runout, and size—all in a fraction of the time it would take using traditional methods. Providing a much greater understanding of the profile and lead of all teeth makes it possible to conduct an advanced waviness analysis resulting in an order analysis of the gear topography including the corresponding amplitudes. Now, potential noise issues like "ghost orders" can be detected, which are not related to the mesh harmonics of the gear and are typically caused by small irregularities created during the manufacturing process or involved

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production machinery. Ghost orders can cause problems once they exceed specific amplitudes. With the advanced waviness analysis and the possibility to inspect up to 100 percent of gears, it is possible to sort out critical parts before they are assembled within the gearbox.

Additionally, the GRSL Quality Center uses *GAMA* (Gleason Automated Measurement and Analysis) software for gear analysis. *GAMA* is a true Windows-based suite of inspection software for all gear geometry types along with gear cutting tools and GD&T measurements. It is easy to use, yet very powerful for gear analyses and flexible reporting and output. Today, *GAMA* has been enhanced to include Advanced Waviness Analysis capabilities, using GRSL's point cloud data of all teeth measurements. Working together, GRSL and *GAMA* can perform comprehensive noise-related detection and analysis in a fraction of the time. Here are a few common, real-world examples:

Large Form Error Detection: The GRSL was tested in an actual scenario where several teeth of a gear were shown to have large form errors. Such form errors are often produced due to manufacturing issues such as a dressing wheel reaching the end of its life and leaving only a few teeth on the gear unfinished. However, finding such conditions using traditional methods can be difficult and very time-consuming. A typical single-flank or double-flank roll tester, for example, won't find such a condition, particularly in this instance where they are of small magnitudes and in negative material. This example (see Figure 1) shows the point cloud collected at the center of the gear in just one rotation. The data extracted from such point cloud on all teeth in a fraction of a second allowed GRSL to easily identify these out-of-tolerance teeth. In addition, the visual information of such conditions, made possible via *GAMA*, is much easier than identifying the same issue based on roll test output.

Tooth Mesh Irregularities: In this real-world application example, the *GAMA* Advanced Waviness software was used to help identify the root cause of noise being emitted from a pinion at first mesh order on the drive flank (left flank). When

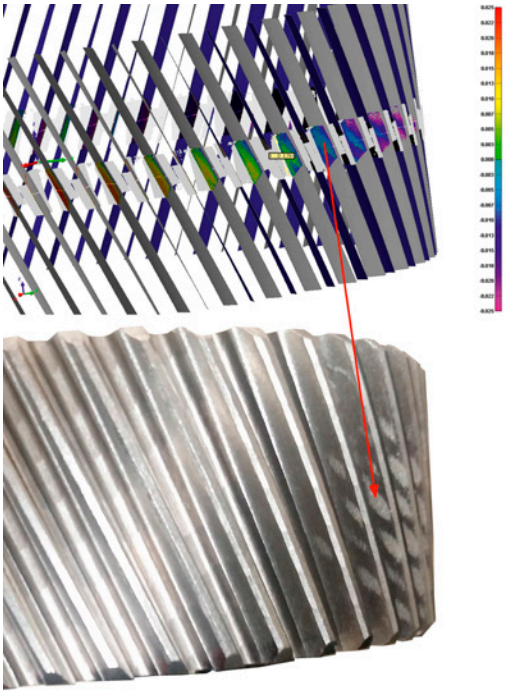

Figure 1—Here, GRSL's point cloud data collection, combined with GAMA software, performs comprehensive noise-related detection and analysis in a fraction of the time of a traditional single- or double-flank roll tester.

a good part was compared to the noisy part using standard inspection methods, the standard charts that were generated showed that the index lead and profile for both gears—good and noisy—were within tolerance (see Figure 2).

However, when a good part and a noisy part were compared using the advanced waviness analysis in an analysis done on the GRSL, it was immediately evident that a first mesh order issue was creating the noise that was detected from the gearbox (see Figure 3). Ultimately, this enabled the manufacturer to remedy the issue through manufacturing-process modifications.

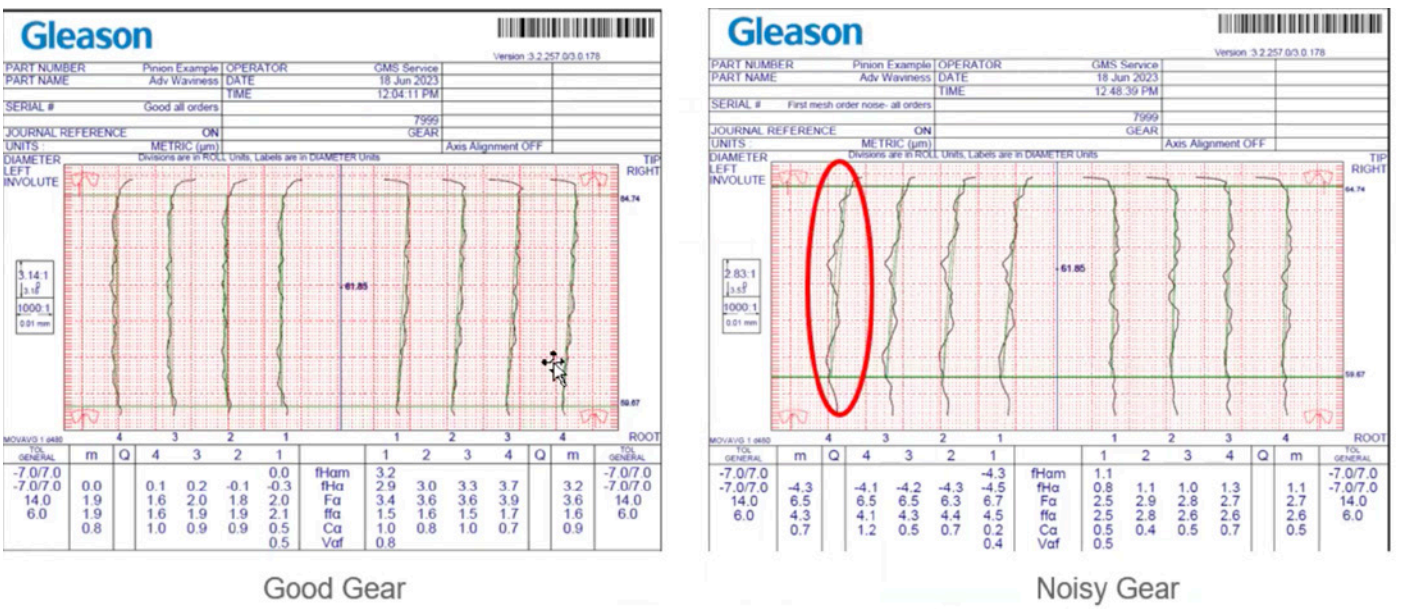

Figure 2—Standard inspection methods show that both a good pinion gear and a noisy pinion gear are within tolerance. The cause of the noise thus goes unidentified.

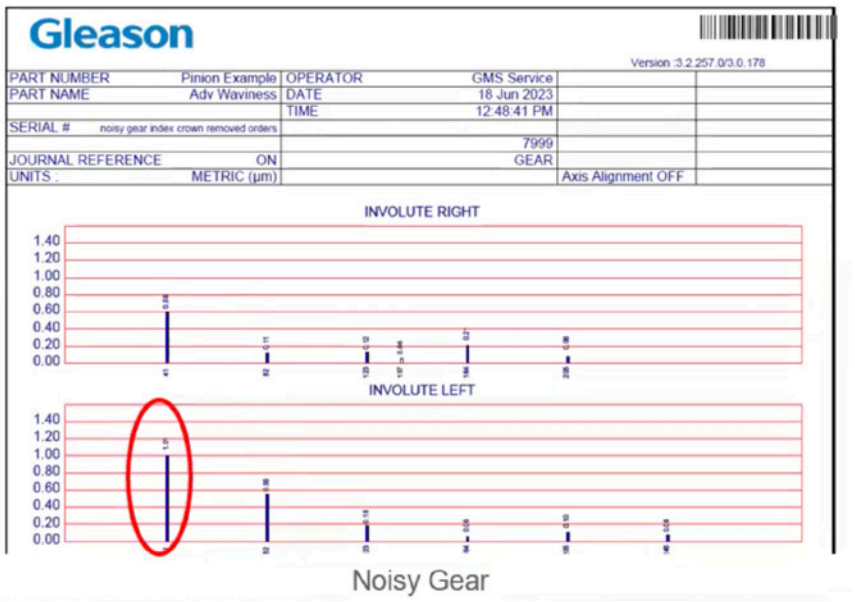

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Figure 3—When the good part and noisy part were compared using the advanced waviness analysis in an analysis done on the GRSL, however, it was immediately evident that a first mesh order issue was creating the noise. Manufacturing-process modifications ultimately remedied the problem.

Summary

The quest for noise reduction, whether for e-drive transmission gears or in a fast-increasing number of other applications, is changing the inspection landscape for manufacturers. Slow, labor-intensive inspection involving multiple systems and operators at different locations is neither desirable, nor effective, and can add considerably to cost. With the arrival of the GRSL Quality Center, as a stand-alone system, connected to various automation systems, or as a fully integrated manufacturing cell, gear manufacturers now have the technology they need to produce gears that can be inspected up to 100 percent of the time, and produced quieter than ever before.

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