Mitutoyo Examines Modern Gear Measurement

Gene Hancz, CMM product specialist, Mitutoyo and
Derek Sporleder, application engineer, Mitutoyo

When it comes to modern gear measurement, there are still essentially two primary tools that shops use. The first is a machine dedicated solely to measuring gears, which had been the primary method for many years, until recently. This type of dedicated machine can provide detailed measurement information that is solely specific to gears and gear teeth, including thickness, width, tooth thickness and pitch diameter. However, this type of machine does not measure characteristics of parts that gears get mounted on to. For this reason, a more flexible, automated option has become progressively more popular.

This second, and increasingly common, tool is a multiuse machine like a Coordinate Measuring Machine (CMM), where gear measuring technology can be added so that gears are one of the many things capable of being measured.

What to Look for When Selecting a Gear Measuring Tool

You need to keep in mind that gears have their own standards of quality. In the U.S., the American Gear Manufacturers Association (AGMA) is responsible for setting those standards. To demonstrate accuracy of gear tooth geometry, up until 2015 AGMA used a rating system created in 2000 called the AGMA 2000-A88 standard, with accuracy grade numbers ranging from Q3 to Q15, where larger numbers indicated a tighter tolerance.

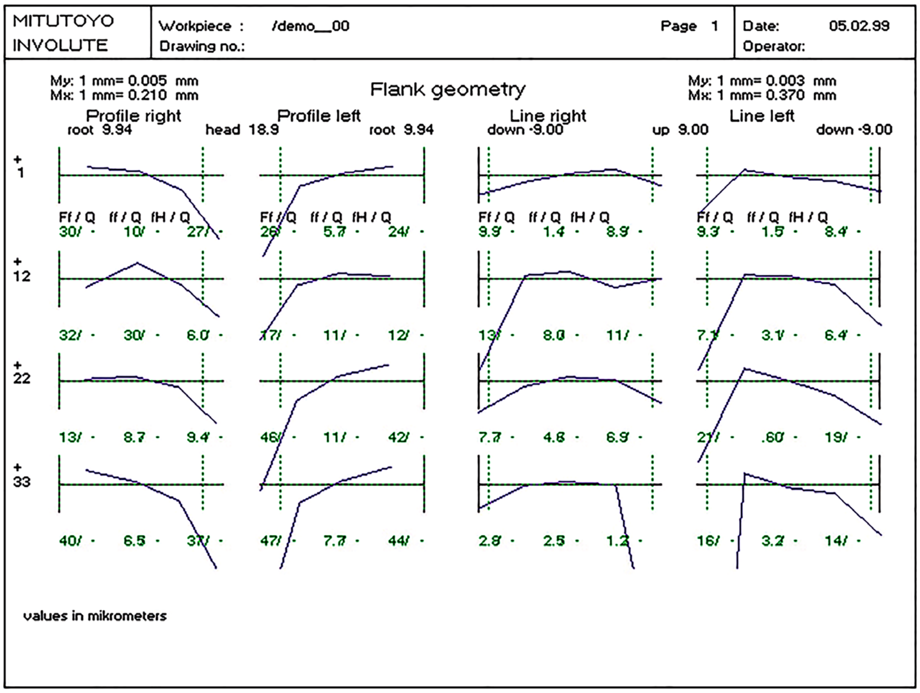
The new standard developed in 2015, the AGMA 2015-1-A01, reduced the number of accuracy grade numbers from 13 to 10, and reversed the accuracy related to such numbers to align better with other international standards. New accuracy grades are designated between A2 and A11, with lower-accuracy numbers signifying a tighter tolerance. In addition, this new standard is a pure metric standard.

DIN standards are another gear rating system that's accepted outside of the U.S., especially in Europe and Germany. In Japan, JIS standards are used. And there are also ISO standards for gears which generally apply outside the United States but do have acceptance in the states. Organizations must be able to adapt to the international standards present in the location where gears are being designed and manufactured.

What all these standards have in common is that the grade or rating comes down to what kind of tolerance you'll have regarding the different gear parameters. And in most cases, it's not one tolerance. For example, for accuracies that are more open, you might end up with multiples in a chart. This allows the gear manufacturer to have control of the geometric accuracy. It depends on whether the application for which the gear will be used calls for a gear that can run quietly or one that is more durable.

Speaking to AGMA standards, specifically, a gear manufacturer must pay close attention to the standard which the gear being produced was based upon. Translating that into machines, a standard CMM length measurement accuracy starts at about 1.7 microns. A CMM of this accuracy class is more than suitable for the inspection of "medium accuracy" and "low accuracy" gears (≈ A7-A11 for the AGMA 2015 standard and Q3–Q8 for AGMA 2000 standard

Depending on the probe-type, a CMM can provide a wide range of gear measurements, including gear-tooth profiles, faster than dedicated gear measurement machines while delivering needed accuracy.



Better technology and software allow a CMM to measure tolerances and other parameters of a gear to determine its quality for specific uses where manufacturing accuracies are more important for different industries and applications.

classes), but as you start to get into a Q9 accuracy grade or A2–A6 accuracy grades, it's time to look for even higher accuracy.

Here, a low-level machine CMM can have a baseline accuracy anywhere from 1.7 microns to 2.2 microns, depending on the probe system. A mid-range accuracy machine begins with a baseline 0.7 microns, which allows for the ability to measure a wider range of accuracy grades as you approach the upper limit of the AGMA threshold. The highest-end machine starts with a baseline accuracy 0.28 microns, and is a lab-grade machine that requires a temperature-, humidity-, and vibration-controlled environment in order to maintain this unparalleled high accuracy.

Which machine you select depends on how critical a gear component is. Is noise an issue? Will it be under a heavy load where teeth could potentially crack or fail? For instance, gears made in the powder metal industry typically only require an AGMA 2000 rating of Q6 or Q7, at most.

Two Cases Where High Accuracy is Needed

We've been talking about standards and accuracy, and there are certain instances when a high-accuracy gear measurement machine would be needed. First is the case of precision watches. These are very expensive, high-end timepieces with extremely small and intricate gears. Gear accuracy and precision are non-negotiable, while gear noise is unwanted.

Second is the case of high-end cars. In these vehicles, the transmission must be both precise and durable. And, as in the case of precision watches, noise is not wanted. In both examples, it's about reaching a balance between the application a gear is used for and the primary goals you want to achieve.

Industries Where Gear Inspection Has Most Changed

Gear inspection has evolved in most industries, but most markedly in the aerospace and automotive industries. In aerospace, planes now require high-efficiency engines and greater transmission-transfer capability. Gears within these mechanisms must function at all altitudes and all temperatures, from 110°F degrees in Arizona as low as -70°F at 35,000 feet. High gear accuracy and durability is required to withstand demanding use in all conditions, which has in turn affected and improved gear manufacturing methods, as well as the process of gear design itself.

In the automotive space, there was a sentiment that the rise in electric cars would make things simpler, gear-wise, without automatic transmissions and the gears involved in gas-powered cars. As it turns out, however, electric cars can be more complex from a gear perspective. In some cases, instead of one electric engine in a vehicle, there are four engines—one for each wheel. This is a dramatic change and requires a learning curve to figure out what gears produce the smoothest transmission of power to achieve the best driver experience while simultaneously requiring the least amount of maintenance.

"It's important that all data and graphs are reported in an easy-to-interpret, visual manner. Today's software options do this and more, generating a customizable table of contents around every parameter evaluated so that even someone who isn't a gear expert can interpret the results with relative ease."

Why "Standard" Gears are Uncommon

When it comes to gears, gear measurement and gear technology, the number one thing you'll find is that you must always start off with a baseline. That baseline is usually derived from what would be considered a standard gear with standard parameters, but then those parameters are tweaked to make the gear optimal for its intended function, which at a fundamental level is to transfer power from one point to another.

Given the parts advancements taking place in many industries, including automotive and aerospace, this means you'll very rarely find or use a standard gear anymore. Sure, standard gears are still made to adhere to AGMA grades and can be bought off the shelf. But because of the specialized nature of most parts today, those standard gears are mostly used as a jumping off point on the way to crafting a more unique and appropriate gear. It's no longer apples to apples. A gear that works on a jet engine to make it safer won't necessarily work on a jet turbo propeller.

Reporting Functions to Look for in Gear Measurement Technology

There will always be different potential parameters and callouts that need to be evaluated based on the accuracy grade of the gear, as well as the intended use. For example, if a gear is going to be under heavy load, maybe it's the tip that gets shifted so teeth don't crack or break. There are modifications that can be applied for measurement, which you need the ability to evaluate.

Therefore, in terms of reporting functions, you may need to evaluate any of a multitude of parameters, including the total pitch or adjacent pitch between the teeth of the gear, profile and lead form error, tooth thickness and base tangent length, and tangential composite error, in addition to what's referred to as measurement over balls or wires and radial runout. The right technology allows you to do this virtually, based on data that's collected while measuring the gear.

You also want to be able to create graphs that show deviations of those measurements compared to what the measurement should be based upon the nominal values entered and the nominal shapes determined in the design phase.

It's important that all data and graphs are reported in an easy-to-interpret, visual manner. Today's software options do this and more, generating a customizable table of contents around every parameter evaluated so that even someone who isn't a gear expert can interpret the results with relative ease.

The Future of Gear Measurement

The future of gear inspection and measurement will become even more automated.

The process of hand measuring will never completely disappear, especially in instances where accuracy isn't important or familiarity with "the way it's always been done" wins out.

However, momentum toward the use of multifunction measuring machines that can accommodate gear measurement tools and software will grow for two reasons: accuracy and cost. For the most part, those who measure gears across all industries require much greater accuracy and precision than hand tools allow. And, many companies are facing a labor shortage combined with tight budgets. They no longer have the time or the capital to devote to workers sitting and taking manual measurements. Workers need to be able to multitask throughout the day.

In the end, it is most likely that the coming decades will be a time when the industry will push for ever-higher measurement quality, and it will be exciting to see what technology advancements develop as a result.

www.mitutoyo.com

A CMM can measure many different types and sizes of gears such as the worm gear pictured.