TOOTH TIPS

BRIAN DENGEL
GENERAL MANAGER • KHK-USA

Precision gearing: Accuracy and tolerances

Understanding the meaning of precision and the real requirements of your application.

When I was a child, one of the great joys of going on the family vacation was to pull out a paper map and review the details of the trip. What highways would we take? What bridges would we cross? What roadside sights would we see along the way? Mom was in charge of making certain that the directions to our vacation hideaway were both accurate and precise. After we packed up the station wagon and headed on our journey, we would inevitably ask, "where are we?" and "when are we going to get there?" This of course was countered with, "Look it up on the map and you can see precisely where we are." This required us to have an accurate understanding of where we were currently driving through. However, the concepts of accuracy and precision were not something we were considering as we traveled to our summer getaway.

When it comes to precision gearing, there is a misnomer that in order to design the best gear system you must use the most precise gears. In reality, the precision quality of the gearing that you should choose is directly dependent on the operating conditions of the application, and overdesigning the gears for the application will result in higher costs and no added benefits.

In order to properly begin this discussion, we first need to better define what precision is. Precision is the ability to perform an action, then repeat the same action, and see the exact same results.

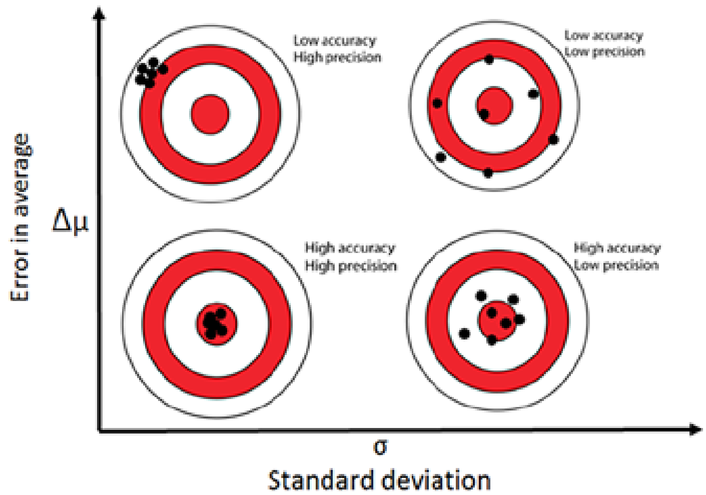

Figure 1: When it comes to precision gearing, a relationship between accuracy and precision does not exist.

For example, if you were to aim at a target and you hit the same area of the target five times consecutively, it would be said that your actions were precise.

Some would argue that if you were able to hit the same area of a target five consecutive times, that your actions would be considered accurate. This is not the case! Accuracy is the ability to perform an

action and have the action strike a desired value. It is independent of precision.

As noted in Figure 1, a relationship between accuracy and precision does not exist.

In the manufacture of gearing, we aim to be both accurate and precise. Accuracy is related to the tolerances assigned to a dimension, and precision is related to the repeatability in manufacturing. In our production facilities, we grade our spur and helical gears using the JIS B1702-1:1998 precision standards. These standards actually assign values for the accuracy of particular parameters of the gear including: Single Pitch deviation f_{pt}, Total Cumulative Pitch deviation F_p, Total Profile deviation F_a, Total Helix deviation F_b,Total Radial Composite deviation F_i``, and Runout F_r.

In order to see how these standards apply, let us consider these parameters of a spur gear to determine the accuracy of the runout under different grades:

a spur gear which is module 2 and has 30 teeth

If the gear grade desired is N5, which is a ground finished tooth, the runout value would be 15 microns. If the gear grade desired is N12, which is an injection molded tooth, the runout value is 171 microns. A hobbed gear would have an accuracy grade of N7, and the runout would be 30 microns.

For a handed cranked application, the N12 gear would be adequate for the application as the motion of the crank is not uniform and geartrain does not need to be precise. For an ordinary motor-driven application that is transmitting simple motion, the N7 gear would be more than adequate. However, if the application requires exact positioning and repeatability then the N5 gear would be the appropriate choice, as this gear is the most accurate.

However, all of this precision would be lost if the tolerancing of the bore is not suitable for the application. For our products, we supply our spur and helical gears with an H7 bore tolerance for our metal products and an H8 bore tolerance for our plastic products. These are both zero plus tolerances meaning that the bore is, at a minimum, the nominal size, and, at a maximum, it is slightly oversized in order to fit a precision shaft. This tolerance range accounts for the deviations in both the accuracy and precision of the bore manufacturing process. It also permits the gear tooth to meet the standards of the gear quality grade for which the gear is being produced.

It is important when designing a gear system to thoughtfully consider the application. Will the environment introduce conditions that negate the precision inherent to the gears you chose? The key points to remember when selecting the quality grade of the gears for your design are:

- The precision does not guarantee accuracy, and
- Tolerances are designed to mitigate deviations in accuracy.

ABOUT THE AUTHOR

Brian Dengel is general manager of KHK-USA, which is based in Mineola, New York. Go online to www.khkgears.us