



**MEASURING
EXCELLENCE
IN *POLYMER*
*GEARING***

While the art may be found in the manufacturing of polymer gears, the science involves measurement, and Kleiss Gears is the expert in combining the two.

By Douglas Felsenthal

At Kleiss we refer to polymer gear making as a “subtle science and exacting art,” and 20 years of experience has shown that a gear is a very special shape that is not well understood from a polymer point of view. Handbooks and textbooks don’t address the subtleties needed to replicate these shapes in high production volumes. The Holy Grail of plastic gear manufacturing is the science of measurement.

Science and mathematics are the key concepts in plastic gear systems. Polymer gear making is broken down into three main components. The foundation is custom gear design directed to the application, followed by precision tooling of a unique shape which includes polymer considerations, completed with precision molding—and the devil’s in the details. All of these are tied together by the ability to measure. Each phase of this continuum brings along attributes which connects the previous step to obtain high repeatability. The end result is a particular shape within a tolerance range as specified by a customer. The question to be answered is: How do



FIGURE 1: WERTH IP/VIDEO VHECK (CMM) SUPPLEMENTED WITH KLEISS POLYMER ANALIZATION SOFTWARE

we demonstrate the shape is attained, and how do we assure that this shape is consistent throughout volume production? This can only be accomplished through precision measurement.

Equipment for precision measurement is not always found off the shelf. It is of particular interest that the reader understands that the real world primarily deals with metal designs and software focused on metal gearing attributes. Polymers are different and require tools and techniques not generally available on the market. This in particular is why quality polymer gearing is difficult to obtain. Most plastic gears are not optimized for strength and create at least 3dba more noise than they should. This is why plastic transmissions fail.

Failure is not an option. The technique that Kleiss has found to obtain success is a very strong foundation in measurement. It is the understanding and mathematical relationships between cavities and output components that gets us to where we want to be. Understanding and measuring this relationship, tightly controlling tooling details and process parameters, results in a highly accurate and repeatable

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molded gear transmission which performs as intended throughout a wide range of operation.

The backbone of the accurate measurement technique is the Coordinate Measuring Machine, or CMM. In our operation we have two, one equipped with a large rotary table, and a new Werth IP/Video check model (fig.1) which has the ability to not only utilize probe measurements but also correlate those to a video system for high speed production checks as needed. As mentioned earlier, the issue is not just the machine, but the machine software and analyzation software to support measurements in a rubber-like environment which can change radically with temperature and humidity. At Kleiss we have gone the extra mile by creating unique software to accurately map the three-dimensional non-linear shrinkage characteristics of plastic gears. We have developed a system of software to use raw data points from our equipment and present them in a fashion that makes sense for polymer products.

As I have mentioned, material vendors publish criteria of shrinkage and tensile strength, etc., based upon very simple geometric shapes. Review figure 2. This figure basically illustrates a gear shape. Consider the shrinkage variations that you see. At best it's non-linear, and though you'll have to take my word for it at this point, it's not equal to the published handbook data. This is precisely why measurement becomes an indispensable tool. Of course, this is only important if you want a consistent part to customer specifications within a tight tolerance range. If all you care about is "squeeze and squirt," then this doesn't apply.

In general, the measurement resolution should be at least an order of magnitude better than the dimension that you are trying to hold. In our case, we find 2.5 microns to be an applicable limit to shoot for.

Another technical secret is automation. When the goal is optimization of repeatability throughout the process, human error and/or simply variation must be removed from the model. As with design, tooling, and process, CNC control is of the utmost importance. Measurement is no different. The CMM process must be automated to gain repeatable results. This is not only important for the manufacturer, but also for the customer who is receiving

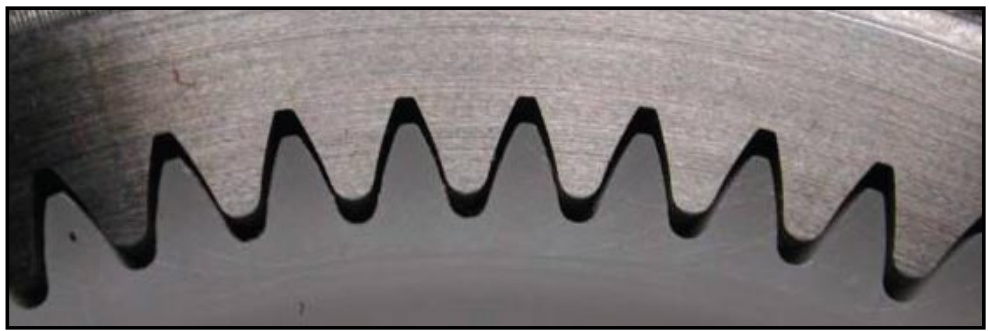


FIGURE 2: NON-TEXTBOOK SHRINK PATTERNS



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FIGURE 3: CNC ROLL TESTER ADAPTED FROM MAHR

material and must repeat measurements for assurance purposes.

One of the biggest assurance areas for measurement reproduction is probe force. Remember that in metal gearing this isn't a factor, but in polymer systems probe sizes are smaller and force can actually approach the deformation point of the part. A probe deflection force of 100 grams is not significant in a metal model. However, in a polymer model, this much force can actually deform the surface we are measuring and give false readings. At least measurements that are not repeatable on a consistent basis. A polymer force model can be as small as 6 grams, and this will make a difference in our poly-

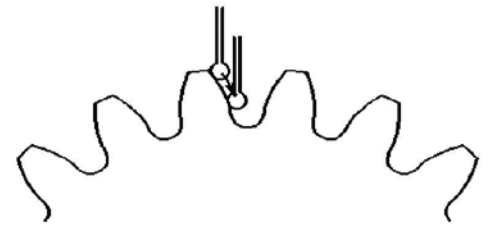


FIGURE 4: TYPICAL PROBE CMM SYSTEM

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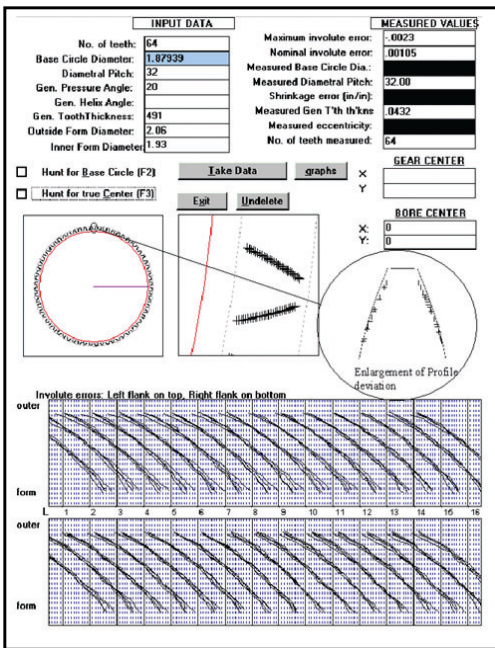


FIGURE 5: KLEISS CMM PROFILE OUTPUT REPORT

mer world. However, the equipment and software from many manufacturers may not address this area properly. Measuring forces of 6 grams yield one measurement and 100 grams of force measure another, which is significant in the under .025 mm world that we are considering.

We were considering CNC automation. Moving a .3 mm probe around by anything other than a CNC automated process can be complete folly. The patterns, hunting process, and shape recognition software must be mathematically driven and consistent, sensing points only obtainable with computer aided design.

Probe measurements are only good down to a certain size of component, of course. Beyond that we must shift to optical methods, which bring into consideration a number other parameters that need to be considered. The old saying that "figures can lie, and accountants figure" is most similar to using optical methods. Under these circumstances a backlighting technique is of vital importance. As Kleiss leadership would say, "What measurement would you like" I'll just adjust the backlighting to obtain it." This can be a problem and must be documented and repeatable for consistent results. 📷

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