Analysis of Form and Contour

Overlay Charts

Since the 1940’s, overlay charts have been used on optical comparators (a.k.a. contour projectors) to evaluate conformance of sample parts to specified tolerances. With this technology, feature surfaces are evaluated relative to tolerance envelopes, as opposed to attempting to quantify the exact size and/or orientation of a geometric feature. (Think of evaluating a circle’s conformance to a tolerance envelope, as opposed to quantifying the exact size of the circle.) Different types of overlay charts cover different permissible degrees of freedom. Examples:

a) Unconstrained – All features on the overlay chart have tolerance envelopes. The operator is free to “jiggle the part” on the stage to the best possible fit relative to the overlay chart’s tolerance boundaries.

b) Fully constrained – Datum features controlling Origin and Rotation are aligned first, and then the rest of the features are evaluated relative to their tolerance envelopes.

c) Partially constrained – A single Origin feature is aligned, but the operator is permitted to rotate the part on the stage to the best possible fit relative to the overlay chart.

d) Constrained to Alignment features with Float permitted by Bonus Tolerance of Datum features.

Today, the permutations of the above examples are clearly identified as variant Profile Tolerance specifications in Section 6 of the ASME Y14.5M-1994 Dimensioning and Tolerancing Standard.

Feature Analysis

Most of today’s computer-controlled automated inspection systems are Feature oriented. This means individual features are measured sequentially and output “resolved” geometries sequentially. However, a set of data points can be expressed as a “resolved” geometry in a variety of ways. For example, the “resolved” geometry of a measured circle may be expressed as:

- Least Squares Best Fit, or
- Maximum Inscribed Circle (MIC), or
- Minimum Circumscribed Circle (MCC), or
- Minimum Radial Separation Circle (MRS)
The inspector has to make judgment calls about which calculation is most suited for the parts being inspected. And what works on a group of parts today may not be the most appropriate for a group of parts received tomorrow – even if they have the same part number.

**Judgment**

Whereas Overlay Chart evaluation can be definitive in a Pass/Fail evaluation, the numerical analysis process employed in measurement software is subject to judgment calls by the part programmer. Common complaints are that the Best Fit result may not agree with results obtained by pin gages, and concurrently, the alternate methods of MIC/MCC/MRS are very dependent on the point density measurement of the feature. This means that a 5-point circle may have a significantly different result than a 100-point circle. This is in contrast to the Overlay Chart methodology in which the entire perimeter of the circle is evaluated.

What's more, feature form and location conformance is not necessarily independent. In many cases, the form and location of multiple features can only be evaluated as a group (see Section 5.4 of ASME Y14.5M-1994 “Feature Pattern Location”).

Feature Pattern Locations are easily identifiable by an operator looking at a part fitted to an overlay chart, because the part as a whole is evaluated at once. The sequentially-based inspection methodologies generally used today to not “measure up” to what was being done 60 years ago.

Overlay charts certainly do have limitations: overall size of the part that can be evaluated at once; time for setup and inspection; difficulty examining extremely small tolerances; etc.

Limitations of overlay charts are largely addressed by today’s automated inspection systems. But the analysis of the part as a whole is seriously lacking in most systems.

**Automatic Evaluation**

So what’s the best way to evaluate parts of varying sizes and tolerances rapidly and with minimal operation involvement? The solution is to combine the automatic measuring machine (Data Acquisition Unit) with post-processing software that “Fits” and compares the measured data to CAD models that incorporate tolerance envelopes as laid out in ASME Y14.5M-1994.

A good post-processing package is tightly integrated with the measurement software. It reports more than just “Go / No Go” status. It quantifies the exact results relative to specific tolerances, thus producing results for process analysis and process control.