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FUNCTIONAL GAGING WITH OPTICAL PROJECTORS

E. S. Roth

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FUNCTIONAL GAGING WITH OPTICAL PROJECTORS
E. S. Roth
Project Leader
Advanced Manufacturing Development Department
Sandia Corporation
Albuquerque, New Mexico

INTRODUCTION

Inspection developments are not keeping up with manufacturing developments. This paper will discuss the direct application of functional gaging principles to the inspection of watch size parts, that can be staged on optical projectors, which will reduce processing time.

The dimensioning and tolerancing methods used are mathematically compatible with Mil-Std-8C and the new ASA Y14.5 standards. The chart gages used are in effect two-dimensional versions of the usual three-dimensional receiver gages that resemble the most critical mating part.

Since most companies still use dimensioning and tolerancing methods that are at least fifty years old, these old-fashioned methods will be discussed in the first half of this paper to expose their limitations. The second half of the paper will cover the more advanced methods outlined in Mil-Std-8C and ASA Y14.5. The same part will be used throughout so the reader can quickly monitor the changes that occur during optical inspection when the method of dimensioning and tolerancing is changed.

The optical chart gage illustrations are highly exaggerated for clarity as only the tolerance zones are increased in scale. Bear in mind that the entire chart gage outline would actually be etched on glass at the same magnifications as the part shadow. The magnifications used mostly are 10, 20, 31.25, 50, 62.5 and 100X.

OLD-FASHIONED METHODS

Figure 1, which was taken directly from the bilateral tolerancing portion of Mil-Std-8C, illustrates the problem faced by the chart gage designer as he must interpret the design gage intent.

Figure 2 shows two possible interpretations that are unfortunately in use. Figure 2A requires a rather strict and variable tolerance on the radius. Figure 2B merely checks length and width, with an added requirement on width contour.

Figures 3A and 3B show several radius interpretations that would be used in conjunction with the chart gage in Figure 2B. In Figure 3A, the chart gage designer looks at the radius as a contour tolerance zone instead of a radius. This chart gage merely requires the part radius shadow, regardless of its actual radius, to fall within the zones in two independent checks at each end of the part. Figure 3B is more of an actual radius check, as the chart gage designer has calculated the actual zone widths that assure him that the part has a specific radius quality. The part radius shadow must lie entirely within one of these smaller zone widths

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to be acceptable. This radius check is performed independently at each end of the part.

Figure 4 shows the basic chart used to independently check each hole for location from each side and end of the part. Figure 5 shows overlay hole centering charts that are to be used in conjunction with the basic chart in Figure 4. Figure 6 shows the independent use of these chart sets which are used as follows:

- Step 1 - Adjust part end shadow so it coincides with the dashed setup lines on the basic chart (Figure 4).
- Step 2 - Center overlay chart (Figure 5) on the hole shadow.
- Step 3 - Observe if the crosshair center on the overlay chart lies within the square tolerance zone on the basic chart gage - it must for acceptance.
- Step 4 - Repeat above steps to check the other hole.

Figure 7 shows three prevalent, and technically invalid, methods of inspecting the hole relationship defined by bilateral tolerances in Figure 1. Figure 7A allows smaller (and more critical holes) a larger tolerance of relation to each other. Figures 7B and 7C are essentially the same and allow larger holes a larger tolerance of relationship - which is a functionally sound approach, but fundamentally opposed to the fixed limits imposed by the .195 - .205 requirement in Figure 1. There is no valid way, except actual measurement methods utilizing the x-y table movement on the projector, to "chart gage" the hole relationship. Figure 9C shows the final chart gage required to measure each hole size.

The previous steps indicate the complexity inherently demanded when attempting to chart gage bilaterally toleranced parts. I have not mentioned the size of many of the tolerance zones shown because that, too, is subject to interpretation and established practices and would expand upon a subject that does not deserve such attention. Needless to say, bilaterally toleranced parts cannot be optically inspected at high production rates and cause nothing but arguments when the chart gage design is critically examined.

HIGHER PRODUCTION RATE METHODS

Figure 8 shows several advanced dimensioning and tolerancing methods, detailed in the true position dimensioning and positional tolerancing sections of Mil-Std-8C and ASA Y14.5. The methods chosen are directly and mathematically suitable to optical chart gages and compare to functional gaging. Surface A is the primary Datum Feature and should be staged so it is perpendicular to the light ray path on the optical projector. The entire outside profile of the part is the Secondary Datum Feature, and is used to locate the hole pattern when it is at MMC (Maximum Material Condition). Each hole has a positional tolerance of .005 inch dia. when it is at MMC (.105 inch dia.) and even more up to a positional tolerance of .010 inch dia. when the holes are .110 inch dia. The part profile must lie within a .005 inch profile tolerance zone all around. Each hole may vary in size from .105 to .110 inch in dia.

Figure 9A shows the chart gage required to check hole location and relation. The profile is the maximum part size (MMC) and the hole location and relation circles, which represent pins, are .100 inch in dia. (.105 MMC hole size minus .005 inch dia. tolerance zone). The outside part profile shadow must lie within the chart profile line and the hole shadows must not touch the .100 circles (pins) for acceptance. Figure 9B is used to check the profile tolerance of the part, and is not combined with the chart gage shown in Figure 9A as it might limit the adjustment of the part shadow by the inspector. (Since the maximum profile shown in Figure 9A has already checked the maximum part size, only one minimum profile tolerance zone is mandatory in Figure 9B). Figure 9C shows the chart gage that would check each hole individually for size.

Figure 10 further increases the inspection process rate as it simplifies the hole size chart gaging operation. The hole relationship is now entirely dependent on finished hole size as no tolerance is allowed if the holes are finished to the more stringent MMC size of a .100 inch dia. (The .100 size is the same virtual (or effective) hole size demanded in the Figure 9A chart with its two .100 inch in dia. chart gage circles). Zero MMC tolerancing, as shown in the Figure 10 specification, merely removes the separate go gaging requirement shown in Figure 9C, which checks the .105 minimum hole size, as the new minimum hole size in Figure 10 is .100 and is checked with the two .100 inch dia. chart gage circles in Figure 11A.

Figure 12 shows the entire part defined using contour tolerance zones and affords the highest inspection processing rate. The contour tolerance zones are a direct definition of the chart gage design and the resulting chart gage requires one step - the entire part shadow must lie within the chart gage lines simultaneously for acceptance.

I do not intend to imply that this final method is the approach we should all take. It is a more stringent acceptance requirement than those shown in the two previous part definitions (Figures 8 and 10) and each will have its place depending on part functional requirements. These advanced methods will, however, simplify both part and chart gage design and significantly increase acceptance rates. Their universal use will enable us to more nearly draw abreast of manufacturing process rates.

Reference: Functional Gaging of Positionally Toleranced Parts
ASTME Manufacturing Data Series Book, 1964

This work was supported by the United States Atomic Energy Commission.

FIG 1

RADIUS CHARTS
FIG 3

A

B

SIZE CHARTS

FIG 2

HOLE LOCATION CHARTS

FIG 4

HOLE CENTERING
OVERLAY CHARTS

FIG 5

HOLE LOCATION CHECK
OVERLAY CHARTS USED
WITH HOLE LOCATION CHARTS

FIG 6

A

B

C

HOLE RELATION CHARTS

FIG 7

FIG 8

FIG 10

A
HOLE LOCATION & RELATION

B
CONTOUR SIZE

C
HOLE SIZE

FIG 9

A
HOLE LOCATION & RELATION

B
CONTOUR SIZE

C
MAX. HOLE SIZE

FIG 11

FIG 12

HIGH PRODUCTION RATE CHART

FIG 13