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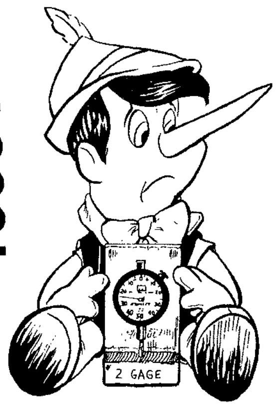

"Pinocchio Doesn't Work Here"

or
Almen Gage Repeatability & Reproducibility

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Suppose your shot peening specification calls for an intensity range of 14 to 16A (.014-.016A). How much of this range (tolerance) is consumed by Almen gage errors or variations in readings? Greater than 30% is generally unacceptable and you must either increase the tolerance or improve your gage. Less than 10% is considered good.

Does your nose seem to grow a little bit longer every time you report an intensity value? Maybe you know that the Almen gage doesn't always tell the truth.

Do you ever get the feeling that your peening process is not in control or that you are probably doing a better peening job than you get credit for? Perhaps your Almen gage isn't cooperating.

How do you check an Almen gage? Very carefully. The attributes of primary interest are:

1. Accuracy
2. Repeatability
3. Reproducibility

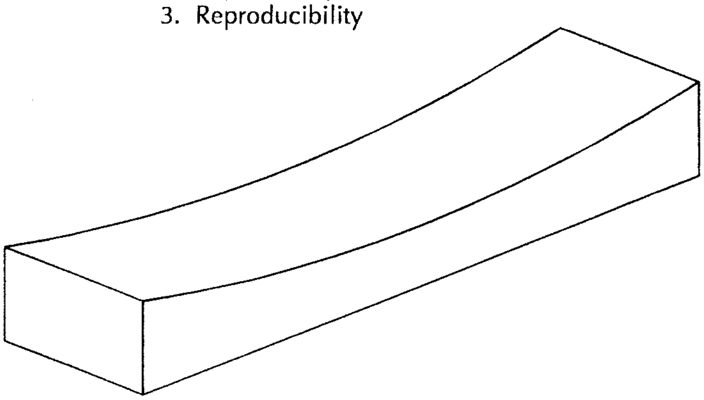

Figure 1

Almen gage **accuracy** can be checked by use of a standard calibration block (Fig. 1) with known radius of curvature. A precision block with radius of 8.24377 inches will provide a reading of .024" ± .0002". Although much more extensive analysis can be done, this procedure can detect the most prominent calibration problems of ball and tip wear.

Almen gage **repeatability** is the variation in measurements obtained with one gage when used several times by one operator while measuring one set of parts.

Almen gage **reproducibility** is the variation in the average of the measurements made by different operators using the same gage when measuring one set of parts.

A standard industrial practice for evaluating gages provides a means of showing equipment variation (EV), appraiser variation (AV) and their combined effects known as repeatability and reproducibility (R&R).

What's needed:

- 1 - Almen Gage
- 3 - Appraisers
- 1 - Data Collection Sheet
- 1 - Administrator
- 10 - Almen Strips

Procedure:

The administrator selects 10 pre-peened Almen strips. These should be representative of a particular peening machine or process. However, any collection of strips will suffice, but the curvatures should be restricted to a range of 4A (for example 4A - 8A or 8A - 12A) to help prevent the operator from memorizing the readings and introducing bias. The strips are then individually identified and numbered 1 through 10.

The administrator presents one strip at a time (in a random sequence) to the appraiser for measurement being careful not to disclose to the appraiser which strip is being measured. The appraiser measures the strip and tells the administrator the value. The administrator records the value, being careful not to let the appraiser see the record. This procedure prevents operator bias. After all ten strips are measured, a second appraiser repeats the process.

When all three appraisers have measured the strips, the strips are then randomly re-ordered and the first appraiser again measures each of the ten strips. This process is repeated until each appraiser has completed three trials each.

The data collected provides insightful information. Evaluation of range errors from each appraiser can identify "good" or "bad" appraiser performance (repeatability). Evaluation of average values from one appraiser to the next can disclose another type of bias (reproducibility).

Typical data collection is shown in Figure 2.

Data for Present Gage *NOTE: Estimate to nearest .0005" for dial indicator type gages*

Operator	A->					B->					C->					Parts
Sample #	1	2	3	Range		1	2	3	Range		1	2	3	Range		Xp
1	0.0080	0.0080	0.0080		1	0.0070	0.0080	0.0080	0.0010	1	0.0070	0.0075	0.0080	0.0005	1	0.0076
2	0.0070	0.0060	0.0065	0.0010	2	0.0060	0.0060	0.0065	0.0005	2	0.0065	0.0065	0.0065		2	0.0064
3	0.0070	0.0070	0.0070		3	0.0070	0.0070	0.0070		3	0.0070	0.0070	0.0070		3	0.0070
4	0.0065	0.0080	0.0070	0.0015	4	0.0070	0.0070	0.0070		4	0.0075	0.0075	0.0075		4	0.0072
5	0.0080	0.0080	0.0080		5	0.0080	0.0070	0.0080	0.0010	5	0.0080	0.0080	0.0080		5	0.0079
6	0.0050	0.0060	0.0065	0.0015	6	0.0065	0.0070	0.0070	0.0005	6	0.0065	0.0065	0.0060	0.0005	6	0.0063
7	0.0085	0.0080	0.0090	0.0005	7	0.0080	0.0085	0.0075	0.0010	7	0.0085	0.0090	0.0085	0.0005	7	0.0085
8	0.0060	0.0070	0.0075	0.0015	8	0.0060	0.0070	0.0070	0.0010	8	0.0075	0.0070	0.0075	0.0005	8	0.0069
9	0.0080	0.0080	0.0080		9	0.0075	0.0075	0.0075		9	0.0075	0.0075	0.0075		9	0.0077
10	0.0090	0.0090	0.0090		10	0.0090	0.0090	0.0090		10	0.0090	0.0090	0.0090		10	0.0090
															Rp=	0.0027

Xa	0.00752
Ra	0.00060

Xb	0.00735
Rb	0.00050

Xc	0.00758
Rc	0.00020

X Diff =	0.00021
R =	0.00043

Figure 2

The formulas in Table 1 will calculate the appraiser variation (AV) and the equipment variation (EV). Lower numbers are better, since this represents variations in measurement. These numbers are presented separately to allow remedial action in either (or both) areas. To get an overall performance index (R & R) the results are combined and shown in Table 2.

$$\overline{R} = \frac{Ra + Rb + Rc}{3} = \frac{.00060 + .00050 + .00020}{3} = .00043$$

$$EV = \overline{R} \times 3.05$$
$$= .00043 \times 3.05$$
$$= .001322$$

$$XDIFF = \max \overline{x} - \min \overline{x}$$
$$XDIFF = .00756 - .00735$$
$$XDIFF = .00021$$

$$AV = \sqrt{(XDIFF \times 2.70)^2 - (EV^2/nr)}$$

$$AV = \sqrt{(.000210 \times 2.70)^2 - (.001322^2/30)}$$

$$AV = \sqrt{(3.266 \times 10^{-7}) - (5.8227 \times 10^{-8})}$$

$$AV = \sqrt{2.6839 \times 10^{-7}}$$

$$AV = 5.1806 \times 10^{-4}$$

$$AV = .000518$$

Table 1

Formulas Used in Computing Variations

$$R\&R = \sqrt{EV^2 + AV^2}$$

$$R\&R = \sqrt{.00132^2 + .000518^2}$$

$$R\&R = \sqrt{2.0151 \times 10^{-6}}$$

$$R\&R = 1.4196 \times 10^{-3}$$

$$R\&R = .001420$$

Table 2

Combining EV and AV for Total R&R

The method of combination is not simple addition. The format of root of the mean of the square of the sums (root-mean-squared or rms) is used since this is a combination of statistical data. This final calculation is referred to as the Gage R & R and is usually the term referred to in gage performance.

It is important to note that when gage R & R is stated as a percentage, then the basis for comparison needs to be stated. Table 3 shows a table of percentages based upon three of the more prominent shot peening intensity tolerances, namely ± .001, ± .002, and ± .005 for tolerance ranges of .002, .004, and .010.

The Shot Peener Almen Gage Study

		+/- .001	+/- .002	+/- .005
If the (total) Peening Tolerance = --->		*0.002*	*0.004*	*0.010*
Equipment Variation	*EV= 0.001322*	*66.1%*	*33.0%*	*13.2%*
Appraisor Variation	*AV= 0.000518*	*25.9%*	*13.0%*	*5.2%*
Repeatability and Reproducibility	*R&R 0.001420*	*71.0%*	*35.5%*	*14.2%*

Table 3

Table of Percentages

From this table above we can see that the performance level of the Almen gage must be appropriate for the specified peening tolerance. If, for example, your peening process requires a range of .002 or 14A - 16A intensity. Then, to have gage variations consume 10% or less of the tolerance the gage must have an R&R rating of .0002. If you find that your gage R&R is greater than .0006, then you are contributing over 30% variation to the measuring process.

If you want to keep your process under control and accurately report the peening intensity then you must insure that your Almen gage doesn't contribute substantial (more than 10%) variation to the measurement process. Remember, over 30% gage variation, relative to the peening tolerance specified, will cause your nose to grow longer. Just ask Pinocchio.

Next: Now that we can declare the degree of measurement variations, we can proceed to (accurately) measure the peening process. In the next issue, we will explore data gathering and presentation methods using common SPC techniques. We'll show you how to quickly display your peening capability on a simple graph and suggest methods to make it look better. It's not difficult and most operators find it to be very beneficial since it gives them a tool to fine-tune their process.

For a more detailed explanation of gage studies see "Measurement Systems Analysis" available from The Shot Peener for $25. Call 1-800-832-5653 for more information.