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SPC and the Almen Strip

Successful Shotpeening Using SPC

If you can't produce consistent Almen strip readings, how can you produce consistent product? This article will show how simple procedures can be used to insure consistent production in conformity with manufacturing specifications. Use of these techniques will reduce costs and increase productivity and quality.

Manufacturing in the past has attempted to meet production requirements by using the sorting process. Eventually, if not enough good units were produced then marginal units were shipped to meet the schedule. When it became necessary to use all, or nearly all, of the production batch in order to meet quotas the acceptance of deviation to specifications was allowed. Instead of using specifications to insure that all parts met requirements, producers tried to change specifications to increase output.

In today's quality conscious market the issue now is how to produce parts with as little variation as possible. In fact, the inspection process itself could be eliminated, provided the manufacturer could produce virtually uniform product. This can only be achieved by studying and eliminating the sources of variation in the process. The producer must eliminate, or greatly reduce, sources of extraneous excessive variation.

The concept of control in variation leads us to a way to achieve this uniform production. While every process exhibits variation, some display controlled variation and others exhibit uncontrolled variation.

The controlled variation is characterized by a stable and consistent pattern of variation over a time period. Any variations that occurred are regarded as chance or random. On the other hand, uncontrolled variation is characterized by a pattern of variation that changes over a period of time. These are not random, but rather, assignable causes, or special causes.

How SPC Improves The Process

When a process displays controlled variation it is classified as stable and consistent. Variations exist that are inherent in the process itself. Therefore, to reduce the variation, the process itself must be changed.

The other case, uncontrolled variation, is changing over time, being inconsistent and unstable. The variation has nothing to do with the way the process was meant to work. The solution is to identify and remove the assignable, or special, causes.

These two approaches are radically different. The second will try to make the process consistent. The first will try to modify a consistent process. The choice depends upon the type of variation present. The first step for improvement, then, is to determine whether or not the process has controlled variations or uncontrolled variations. This is where the control chart helps.

The goal of continuous product improvement results in achieving a state of statistical process control and production of 100% conforming parts. Neither achievement is permanent and both are reversible. The combinations lead to four categories that summarize the process:

Ideal State: Process in control-100% conforming parts
Threshold State: Process in control - some nonconforming parts
Brink of Chaos: Process out of control - 100% conforming parts
Chaos: Process out of control-some nonconforming parts

The ideal state implies that all of the product is suitable for the intended purpose, and since it is in control the variation present is consistent over time. This process will produce good product hour after hour, etc. as long as it remains in control.

1. The process must be inherently stable over time
2. The manufacturer must operate the process in a stable and consistent manner and no arbitrary changes are allowable
3. The process average must be set and maintained at the proper level.
4. The natural tolerance must be less than the specification tolerance for the product.

Since all process tends to migrate to chaos (entropy), it is absolutely essential to continuously monitor the process with control charts. The producer must identify the effects of entropy and the presence of special or assignable causes. No other tool will reliably and consistently display the information as the control chart.

The SPC Control Chart

The SPC control chart is used to show the average performance and range of values. These two indicators will help describe the process and identify controlled or uncontrolled variations.

The sample size, n, is chosen to provide averaging of values, or location of the process. Typically two to five samples are used. The difference between the maximum and minimum sample describe the range and will provide a measure of process dispersion.

The control chart shows a collection of data and the results that are plotted over time. The upper chart is the average of the sample group, and the lower chart is the range. Interpretation of the data is needed to indicate whether the process is in control or not. The chart should show points above and below the average line. Although the points may lie within the limits, a trend of points may indicate special or assignable causes are present which can lead to unpredictable future results.

The technique of successful control chart interpretation is outside the scope of this article. For additional information see "Understanding Statistical Process Control" by Wheeler and Chambers, available through The Shot Peener.

The use of control charts to monitor the shot peening process is only a first step required in a complex process. However, knowing what the Almen strips are doing is a powerful tool in observing the process. Additional tools, such as targeting, coverage, continuous monitoring of speed (air pressure or wheel rpm) and shot flow rate, also need to be used. Remember, only those processes operated with control charts are likely to achieve and maintain the ideal state. All others are subject to deterioration and chaos.

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STATISTICAL PROCESS CONTROLS, INC.

AVERAGE and RANGE CHART

5 65 25

CHART NO. | PART NO.

PRODUCT: Cluster Gear

MEASUREMENT: Almen Strip "A" Arc Height

UNIT OF MEASURE: .001

ZERO EQUALS: .010"

DATE	6-6-88				6-7-88				6-8-88				6-9-88				6-10-88				6-11-88				
TIME	8:00	10:00	2:00	4:00	8	10	2	4	8	10	2	4	8	10	2	4									
SAMPLE MEASUREMENTS 1	11.3	12.4	12.7	13.8	12.4	12.3	12.4	12.3	13.4	12.5	13.6	12.0	15.1	12.9											
2	11.9	12.8	13.8	12.3	13.9	13.6	12.2	12.9	13.1	14.8	15.4	16.0	13.6	13.8											
3																									
4																									
5																									
SUM	23.2	25.2	26.5	26.1	26.3	25.9	24.6	25.2	26.5	27.3	29.0	28.0	28.7	26.7											
AVERAGE	11.6	12.6	13.3	13.1	13.2	12.9	12.3	12.6	13.3	13.7	14.5	14.0	14.3	13.3											
RANGE	.6	.4	1.1	1.5	1.5	1.3	.2	.6	.3	2.3	1.8	4.0	1.5	.9											

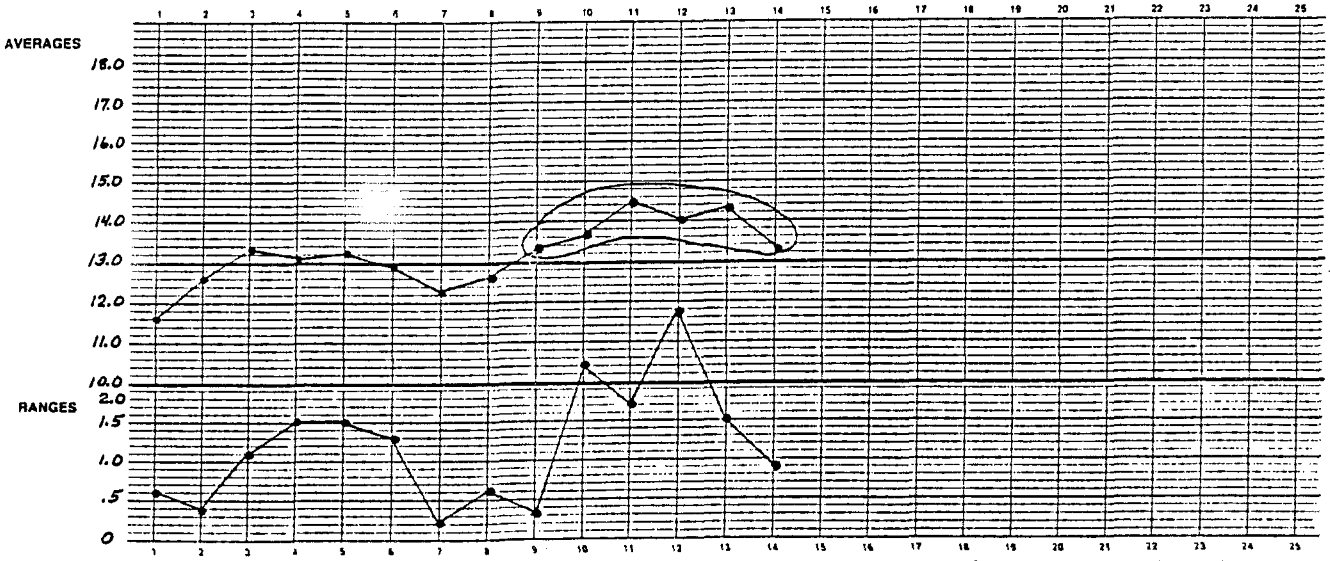

TABLE OF CONSTANTS FOR $\bar{X}$ & R AND MEDIAN RANGE CHARTS

SAMPLE SIZE n	A_2	d_2	D_3	D_4	$\tilde{A}_2$	$\tilde{D}_3$	$\tilde{D}_4$
2	1.880	1.128	—	3.267	1.880	—	3.267
3	1.023	1.693	—	2.574	1.187	—	2.574
4	0.729	2.059	—	2.282	0.796	—	2.282
5	0.577	2.326	—	2.114	0.691	—	2.114
6	0.483	2.534	—	2.004	0.548	—	2.004
7	0.419	2.704	0.076	1.924	0.508	0.076	1.924
8	0.373	2.847	0.136	1.864	0.433	0.136	1.864
9	0.337	2.970	0.184	1.816	0.412	0.184	1.816
10	0.308	3.078	0.223	1.777	0.362	0.223	1.777

FOR n > 10 SEE PAGE 51 IN THE CONTINUOUS PROCESS CONTROL AND PROCESS CAPABILITY IMPROVEMENT BOOKLET — JULY 1983

C_p AND C_{pk} INDEXES

CAPABILITY ANALYSIS

$$\hat{\sigma} = \bar{R}/d_2$$

CAPABILITY POTENTIAL

$$C_p = \frac{\text{SPECIFICATION WIDTH}}{6\hat{\sigma}}$$

C_p & C_{pk} OF 1.00 OR GREATER IS REQUIRED FOR CAPABILITY

CAPABILITY PERFORMANCE

$$C_{pk} = \frac{Z_{MIN}}{3}$$

Z_{MIN} = SMALLEST VALUE OF:

$$Z_{USL} = \frac{USL - \bar{X}}{\hat{\sigma}}$$

$$Z_{LSL} = \frac{LSL - \bar{X}}{\hat{\sigma}}$$

USL = UPPER SPECIFICATION LIMIT
LSL = LOWER SPECIFICATION LIMIT

IMPORTANT: PROCESS MUST BE IN STATISTICAL CONTROL TO PERFORM ACCURATE CAPABILITY ANALYSIS, I.E., C_p AND C_{pk} — NOTE PROCESS CONTROL GUIDELINES FOR DETERMINING IF A PROCESS IS IN STATISTICAL CONTROL.

GUIDELINES FOR INTERPRETATION OF A PROCESS IN STATISTICAL CONTROL

CONTROL CHART (AVERAGES)

Single point out — UCL

Zone A 2 out of 3 in Zone A or above

Zone B 4 out of 5 in Zone B or above

Zone C 7 in a row in Zone C or above

— $\bar{X}$

Zone C 7 in a row in Zone C or below

Zone B 4 out of 5 in Zone B or below

Zone A 2 out of 3 in Zone A or below

Single point out — LCL

SPC CONTROL CHART APPLICATION AND FORMULAS

TYPE OF DATA	CONTROL CHART	SAMPLE SIZE(n)	CONTROLLED	CENTERLINE	CONTROL LIMITS	FEATURE
VARIABLE	$\bar{X}$&R CONTROL CHART	VARIES 2 & UP (5 MOST PREFERRED)	$\bar{X}$: VARIATION OF MEAN VALUE R: VARIATION OF RANGE	$\bar{\bar{X}}$ $\bar{R}$	$\bar{\bar{X}} \pm (A_2\bar{R})$ $D_4\bar{R}$ $D_3\bar{R}$ = n≥7	BASIC CONTROL CHART. EFFECT AND PRECISION IS SUPERIOR
VARIABLE	$\tilde{X}$&R CONTROL CHART OR MEDIAN & RANGE	VARIES 2 & UP (3, 5 ARE PREFERRED)	$\tilde{X}$: VARIATION OF MEDIAN VALUE R: VARIATION OF RANGE	$\bar{\tilde{X}}$ $\bar{R}$	$\bar{\tilde{X}} \pm (\tilde{A}_2\bar{R})$ $\tilde{D}_4\bar{R}$ $\tilde{D}_3\bar{R}$ = n≥7	CALCULATION IS SIMPLE AND PLOTTING IS EASY. GOOD MULTI-SPINDLE OR CAVITY APPLICATIONS
VARIABLE	X CONTROL CHART (MOVING AVERAGE) (MOVING RANGE)	1	WHEN ADEQUATE GROUPING IS IMPOSSIBLE OR DIFFICULT	$\bar{X}$ $M\bar{R}$	$\bar{X} \pm 2.66(\bar{R})$ OR $\bar{X} \pm 2.66(M\bar{R})$	USED WHEN ADEQUATE GROUPING IS IMPOSSIBLE. DEVELOPS LARGE CONTROL LIMITS. NOT AS SENSITIVE
ATTRIBUTE	p CONTROL CHART	CHANGEABLE	$p = \frac{np}{n}$ RATIO OF REJECTS	$\bar{p}$	$\bar{p} \pm 3\frac{\sqrt{\bar{p}(1-\bar{p})}}{n}$	VARYING SAMPLE SIZES CAN BE USED. CALCULATIONS OF CONTROL LIMITS CAN BE DIFFICULT
ATTRIBUTE	np CONTROL CHART	CONSTANT	np NUMBER OF REJECTS	$n\bar{p}$	$n\bar{p} \pm 3\sqrt{n\bar{p}(1-n\bar{p})}$	USED FOR A LOT WITH A CONSTANT SAMPLE SIZE
ATTRIBUTE	c CONTROL CHART	CONSTANT UNIT	c NUMBER OF NONCONFORMITIES IN A CONSTANT UNIT	$\bar{c}$	$\bar{c} \pm 3\sqrt{\bar{c}}$	USED SOMETIME
ATTRIBUTE	u CONTROL CHART	CHANGEABLE INCONSISTENT UNITS	$u = \frac{c}{n}$	$\bar{u}$	$\bar{u} \pm 3\sqrt{\frac{\bar{u}}{n}}$	USED RARELY

RECOMMENDED ACTIONS FOR OUT OF CONTROL SIGNALS

1. Verify plotted points.
2. Confirm measurement system has not changed.
3. Take an additional sample (subgroup) if the point remains out of control — look for an assignable cause(s) — see #4.
4. Use the 4m's of problem solving. Is it the
   1. Machine? 3. Method (gaging)?
   2. Material? 4. Man?
5. Write on the control chart the assignable cause or your ideas as to what it possibly could be.
6. Attempt to eliminate the assignable cause(s).
7. If the assignable causes can not be eliminated or identified, notify your immediate supervisor.

OUT OF CONTROL SIGNALS

1. Points outside of upper or lower control limits
2. 6 points in a row that trend up or down
3. 7 points in a row above or below the $\bar{X}$ line
4. More than 2/3 of the points in zone C
5. 4 out of 5 points in zone B or below
6. 2 out of 3 successive points in zone A or below