

BASIC TOOL

USING A GRAPHICAL TECHNIQUE FOR DETERMINING AND DISPLAY PROCESS CAPABILITY

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Introduction

Capability indices seem to be the latest fad in judging product quality. As a Statistical Process Control (SPC) coordinator I am often asked questions such as, what is the Cpk of your process without any regard to process stability or distribution shape. One quick approach to assess the capability of your process is to calculate multiple capability indices (such as Cpk) over time and to plot these numbers on an \bar{X} mR control chart, along with a histogram of the individual values. Although not an exact method, by calculating and charting capability ratios over an extended period of time instead of providing a one time value, a clearer picture of your processes' capability can be established. The following example uses 3 statistical tools in order to evaluate and display process capability of a die bond operation.

Basic Tools used to Perform the Capability Study

- \bar{X} and R control chart
- XmR control chart
- Histogram

Formulas used to Perform Study

- Estimated standard deviation = $\bar{R}/d2$
- $Cpk = \bar{X} - LSL/3 (\bar{R}/d2)$

Description of the Die Bond Process

An automatic die bonder picks silicon die from a wafer and places each die onto a thin layer of conductive epoxy which has been deposited on a ceramic substrate for bonding. After the die and epoxy have been cured for 1 hour, a sample is tested for bond strength. A die strength tester records the force required (in grams) to shear off a die. A 3 piece sample is sheared every 2 hours and the results are recorded on a \bar{X} and R control chart (Figure 1). The resulting control chart displays statistical control and therefore qualifies for a process capability study. The capability study compares the natural process limits to the product test specification. For the die bond operation, the lower spec limit (LSL) is 400 grams. There is no upper spec limit (USL).

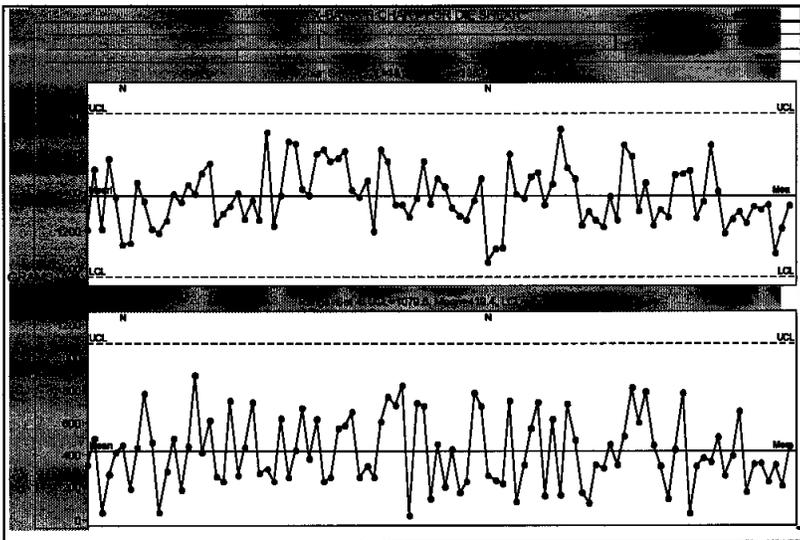


Figure 1

practitioners as to what constitutes a stable process (statistical process control) because of the various detection rules and the fact that **no** process is always stable, for this example statistical process control will be defined as 35 consecutive subgroups of size 3 without any points outside the control limits (also known as Western Electric Zone Test 1). The last 100 subgroups from the die bond process show no values beyond the control limits on either the \bar{X} or R control chart.

Step 2: For the die bond process each weeks' data from the \bar{X} and R control chart is collected and the following statistics are calculated:

- The estimated process standard deviation ($\bar{R}/d2$)
- The process mean (\bar{X})

A Graphic Display of Process Capability for the Die Bond Operation

Step 1: Verify that the process displays a reasonable degree of statistical process control. Capability studies should only be performed on stable and predictable processes. Although there is no agreed upon definition among SPC

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Step 3: Calculate a Cpk value for each weeks' data using the following formula:

$$Cpk = \bar{X} - LSL / 3(\bar{R}/d2)$$

Cpk values for weeks 1 through 8

Week 1: 1.253

Week 2: 1.900

Week 3: 1.294

Week 4: 1.201

Week 5: 1.364

Week 6: 1.242

Week 7: 1.579

Week 8: 1.454

Step 4: Plot each weeks Cpk numbers on an Individuals Control chart (also known as a XmR chart). The X axis represents time (weeks) while the Y axis represents Cpk values (Figure 2).

Step 5: Calculate control limits and averages lines for both the X chart and the mR chart. Wait until you have collected about 8-10 weeks worth of data before setting limits. (Figure 2).

Step 6: Construct a histogram of the individual values (Figure 3). Here the last 100 subgroups (300 individual readings) covering approximately 2 months worth of data were used to generate this histogram. Note: When the raw data is skewed, as in this example, there will be a slight skew in the sample means which are rough approximations.

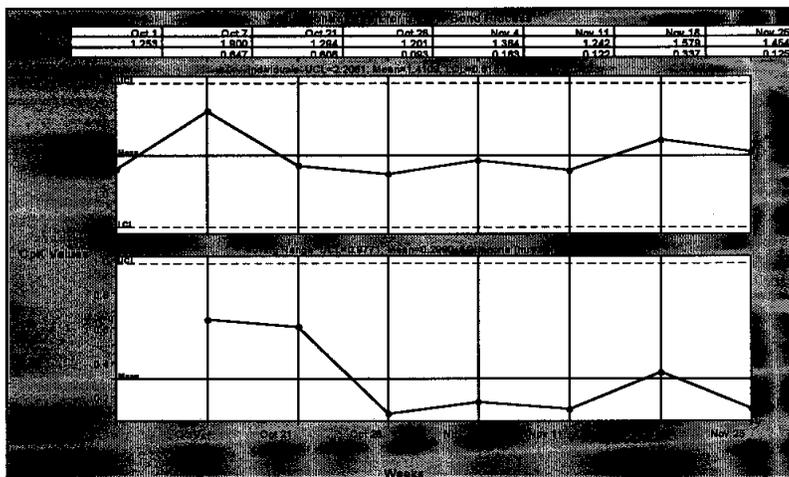


Figure 2

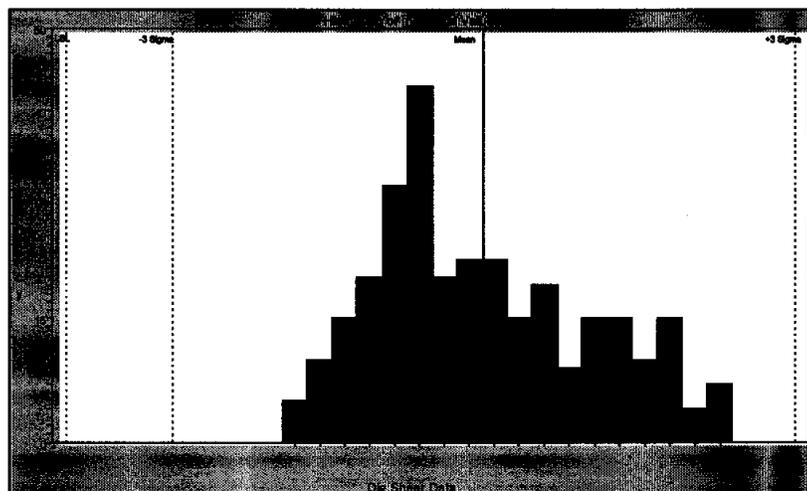


Figure 3

Interpretation of Cpk Control Chart and Histogram

The XmR control chart of the Cpk values displays a predictable capability. The mean of the X chart is 1.41. This is the best estimate of process capability for the die bond operation. The histogram of the individual values (300 readings) show all the values well within the specification limit (400 grams). It also shows a distribution shape that is skewed to the high side. This suggests that the average Cpk value of 1.41 is most likely a conservative estimate of process capability.

Summary

All statistics vary over time, capability indices such as Cpk are no exception. In order to help establish a more realistic picture of your process-

es' capability, one should always use multiple values. A large sample size is required to ensure a valid estimation. By using graphs which show the performance of your process over time (such as an XmR control chart) one can easily generate meaningful capability indices. In addition, knowing the shape of your distribution of data by constructing a histogram will help you to better interpret these capability values. Finally, one should always keep in mind that only stable and predictable processes can be used when one is performing a capability analysis.

BIBLIOGRAPHY

Wheeler, Donald J. "Advanced Topics in Statistical Process Control" (Knoxville, Tenn: SPC Press, 1995)