Key Words

- accuracy
- control chart
- control limits
- fishbone diagram
- histogram
- nominal
- parent population
- poka-yoke
- precision
- process capability (PC)
- quality control (QC)
- range (R)
- sample mean ($\bar{X}$)
- sample size ($n$)
- self-checking
- source inspection
- specification limit
- standard deviation ($\sigma$)
- statistical process control (SPC)
- Taguchi methods
- total quality control (TOC)
- variability

Review Questions

1. Define a process capability study in terms of accuracy or precision.
2. What does the nature of the process refer to?
3. Suppose you have a “pistol-shooting” process that is accurate and precise. What might the target look like if, occasionally while shooting, a sharp gust of wind blew left to right?
4. What are the steps required to making a PC study of a process?
5. Why don’t standard tables exist detailing the natural variability of a given process, such as rolling, extruding, or turning?
6. What are Taguchi or factorial experiments, and how might they be used to do a process capability study?
7. How does the Taguchi approach differ from the standard experimental method outlined in this chapter?
8. Why are Taguchi experiments so important compared to classical DOE-type experiments?
9. Here are some common, everyday processes with which you are familiar. What variable or aspect to the process might dominate the process in terms of quality, not output?
   a. Baking a cake (from scratch) or grilling a steak
   b. Mowing the lawn
   c. Washing dishes in a dishwasher
10. Explain why the diameter measurements for holes produced by the process of drilling could have a skewed rather than a normal distribution.
11. Name some common manufactured items that may receive the following:
    a. 100% inspection
    b. No final inspection
    c. Some final inspection, that is, sampling
12. What are common reasons for sampling inspection rather than 100% inspection?
13. Fill in this table with one of the four following statements: no error—the process is good; no error—the process is bad; type I or alpha error; type II or beta error.

<table>
<thead>
<tr>
<th>The sample suggested that the process had:</th>
<th>In reality, if we looked at everything the process made, we would know that it had:</th>
</tr>
</thead>
<tbody>
<tr>
<td>changed</td>
<td>not changed</td>
</tr>
<tr>
<td>The sample</td>
<td></td>
</tr>
<tr>
<td>changed</td>
<td>not changed</td>
</tr>
</tbody>
</table>
14. Explain why, when we sample, we cannot avoid making type I and type II errors?
15. Which type of error can lead to legal action from the consumer for a defective product that caused bodily injury?
16. Define and explain the difference between each of these:
    a. $\sigma$ and $\bar{X}$
    b. $\sigma$ and $\bar{X}$
    c. $\sigma$, $\sigma_1$, and $\sigma_2$
17. What is $C_p$, and why is a value of 0.80 not good? How about a value of 1.00? 1.3?
18. The designer of a component usually sets the nominal and tolerance values when designing the part. How do these decisions affect the decisions of the manufacturing engineer (MIE)?
19. What are some of the alternatives available to you when you have the situation where $6\sigma > USL - LSL$?
20. $C_{pk}$ is also a process capability index. How does it differ from $C_p$?
21. In a sigma chart, are values for the samples normally distributed about $\bar{X}$? Why or why not?
22. What is an assignable cause, and how is it different from a chance cause?
23. Why is the range used to measure variability when the standard deviation is really a better statistic?
24. How is the standard deviation of a distribution of sample means related to the standard deviation of the distribution from which the samples were drawn?
25. In the last two decades, the quality of automobiles has significantly improved. What do you think is the main cause for this marked quality improvement?
26. Figure 36-12 shows a bimodal check sheet indicating that the two operators performing an assembly task (in a cell) do the jobs at different rates. What would you recommend here?
27. Control charts use upper and lower control limits. Is a UCL the same as a UCL?
28. In Figure 36-14, what are the USL and the LSL and why are they not shown on the charts?
29. What are four major branches (fishbones) on a cause-and-effect diagram?
30. How does variation in the measuring device (instrument) affect the measurements obtained on a component?
31. Explain what happened to improve the process in Figure 36-18.
32. In Table 36-1, explain these:
   a. MO-CO-MOO
   b. 8-4-8-4 scheduling
   c. $n = 2$ inspection
   d. Pareto chart
33. What is a quality circle, and how might you apply this concept to your college life?
1. For the items listed in the following chart, obtain a quantity of 48. Measure the indicated characteristics and determine the process mean and standard deviation. Use a sample size of 4, so that 12 samples are produced.

<table>
<thead>
<tr>
<th>Item</th>
<th>Characteristic(s) You Can Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat washer</td>
<td>Weight, width, diameter of hole, outside diameter</td>
</tr>
<tr>
<td>Paper clip</td>
<td>Length, diameter of wire</td>
</tr>
<tr>
<td>Coin (penny, dime)</td>
<td>Diameter, thickness at point, weight</td>
</tr>
<tr>
<td>Your choice</td>
<td>Your choice</td>
</tr>
</tbody>
</table>

2. Perform a process capability study to determine the PC of the process that makes M&M candy. You will need to decide what characteristics you want to measure (weight, diameter, thickness, etc.), how you will measure it (use rule of 10), and what kind of M&Ms you want to inspect (how many bags of M&Ms you wish to sample). Take sample size of 4 \( (n = 4) \). Make a histogram of the individual data and estimate \( \mu \) and \( \sigma \) as outlined in the chapter. If you decide to measure the weight characteristics, you can check your estimate of \( \mu \) by weighing all the M&Ms together and dividing by the total number of M&Ms.

3. For the data given in Figure 36-4, compute the mean and standard deviation for the histogram and then \( C_p \) and \( C_{pk} \), making any assumptions needed to perform the calculations.

4. For the data given in Figure 36-7, compute \( C_p \) and \( C_{pk} \).

5. Calculate \( \bar{X} \) and \( \bar{R} \) and the control limits for the \( \bar{X} \) and \( R \) control charts shown in Figure 36-A. The sample mean, \( \bar{X} \), and range, \( R \), for the first few subgroups and the data for each sample are given in the bottom of the figure. There are 25 samples of size 4. Therefore \( k = 25, \ n = 4 \). Complete the bottom part of the table and then compute the control limits for both charts. Construct the charts plotting \( \bar{X} \) and \( R \) as solid lines and control limits as dashed lines, as shown in Figure 36-14. The first four data points have been plotted and the points

\begin{align*}
\bar{X} &= \text{Average} = \\
\bar{R} &= \text{Average} = \\
\text{UCL} = \bar{X} + A_2\bar{R} = \\
\text{LCL} = \bar{X} - A_2\bar{R} = \\
\text{Ranges (R chart)} &= \\
\text{UCL} = D_4\bar{R} = \\
\text{LCL} = D_3\bar{R} = \\
\text{Averages (\bar{X} bar chart)} &= \\
\text{For first subgroup:} \\
\bar{X} &= 2.65 - 4 = 0.6628 \\
R &= 0.05
\end{align*}

FIGURE 36-A
connected, but are they all correctly plotted? Replot any points that are incorrectly plotted. Plot the rest of the data on the charts and comment on your findings. (Use Figure 36-14 as a comparison.)

6. For the data given in Figure 36-A, estimate the mean and standard deviation for the process from which these samples were drawn (i.e., the parent population) and discuss the process capability in terms of $C_p$ and $C_{pk}$. The USL and LSL for this dimension are 0.9 and 0.5, respectively, and the nominal is 0.7.

7. Figure 36-B contains data from a machining process that produces holes (drilling) with limits of 6.00 to 6.70 mm. The control charts for $X$ and $R$ using $n = 5$ and $k = 25$ are also shown in the figure. (Note: The numbers in the body of the table are 6.47, 6.19, 6.19, 6.29, etc.)

1. Recheck the calculation of the mean values and the range values for the 25 samples and then check the calculations for $\bar{X}$ and $R$ and the control limits for the charts.
2. Insert the centerlines for $\bar{X}$ and $R$ on the charts.
3. Check the plotting of the points on the charts.
4. Discuss the charts.
5. Using the data to develop the process capability indexes and discuss the capability of this process.
6. Using the data $n = 5$ and $k = 25$, develop the $\sigma$ control chart and use $\sigma$ to estimate $\sigma$ for the process capability indexes and $C_p$ and $C_{pk}$.
7. Develop $\bar{X}$ and $R$ charts for sample sizes of 4 (or 3) by ignoring $X_1 (X_2$ and $X_3$) or any combination of individual values. Use the charts to perform a process capability study. Did the findings change?