What is quality?

1. What is quality?
2. Variations
3. Statistical representation
4. Robustness

Read Chapter 35 & 36

Variations

1. Part and assembly variations
2. Variations in conditions of use
3. Deterioration

Variable Outcome

Results from measuring intermediate or final process outcome

- Men
- Machines
- Materials
- Methods

Outcome is measured:
- Unit of measure (mm, kg, etc.)
- The measurement method must produce accurate and precise results over time

Outcome examples:
- Shaft O.D. (inches)
- Hole distance from reference surface (mm)
- Circuit resistance (ohms)
- Heat treat temperature (degrees)
- Radiator transit time (hours)
- Engineering change processing time (hours)
Technological Development

- Physical masters
- Engineering drawings
- Go / No-Go gage
- Statistical measurement
- Continuous on-line measurement

Engineered Part

- Design specification
  \[ \pm 0.004' \]
- Process specification

Engineered Part (cont’d)

- Raw data, \( n = 20 \)

\[
\begin{array}{llllll}
1.0013 & 0.9986 & 1.0015 & 0.9966 \\
1.0080 & 0.9987 & 1.0029 & 0.9977 \\
1.0042 & 0.9955 & 1.0019 & 0.9970 \\
0.9982 & 1.0024 & 0.9965 & 1.0022 \\
1.0020 & 0.9960 & 1.0013 & 1.0020 \\
\end{array}
\]

- 6 Buckets

\[
\begin{array}{ll}
0.994 - 0.996 & 2 \\
0.996 - 0.998 & 2 \\
0.998 - 1.000 & 5 \\
1.000 - 1.002 & 6 \\
1.002 - 1.004 & 3 \\
1.004 - 1.006 & 2 \\
\end{array}
\]

Manufacturing Outcome: Central Tendency

Central Tendency

Halloween M&M mass histograms: \( n = 100 \)

- 8 Buckets
Dispersion

Normal Probability Density Function

\[ f(x) = \frac{1}{\sqrt{2\pi} \sigma} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \]

Probability

\[ P_a \leq x \leq b) = \int_a^b f(x) dx \]

\[ P(-\infty \leq x \leq a) = \int_{-\infty}^a f(x) dx = 1 \text{ for } \mu = \sigma \]

Normalized

\[ z = \frac{x - \mu}{\sigma} \]

\[ P(a \leq z \leq b) = \int_a^b f(z) dz \]

Statistical Distribution

• Central tendency
  – Sample mean (arithmetic): \[ \overline{x} = \frac{\sum x_i}{n} \]
  – Sample median

• Measures of dispersion
  – Standard deviation
  – Variance
  – Range

Areas under the Normal Distribution Curve

Normal Distribution Example

Take a M&M with mass = 0.9g, based on our calculated normal curve, how many M&M’s have a mass greater than 0.9g?

\[ Z = \frac{x - \mu}{\sigma} \]

\[ Z = (0.9 - 0.89876) / 0.04255 = 0.29 \]

Area to the right of Z=0.29, from table on previous page:

\[ P = (1 - 0.6141) = 0.3859 \]

So, the number of M&M’s with a mass greater than 0.9g is \[ P \times n = 0.3859 \times 100 = 39 \]
Robustness

A Tale of Two Factories

Tokyo

San Diego

Diego

T-5 T T+5

D

C

B

A

B

C

D

Quality Loss

$100

T-5 T T+5