Can you Trust your Process Capability Studies

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75 Minute Agenda

- Introduction to PCS
- Customer Perspective
- Capability Defined
- Short-Term v. Long-Term
- Measurement Issues
- Distribution Issues
- Conducting Studies
- Interpretation of Study
- Conclusions & Actions
- Wrap Up – Q&A

Process Capability Studies (PCS)
Data Use

Why Collect and Track Data
– Data → Information → Decision
– Understand – Evaluate – Control – Predict

Objective of Capability Studies
– Predict the performance of a process to specifications
– Provide short-term capability (Cpk)
– Predict long-term performance (Ppk)
– Baseline for improving the process
Why care about Process Capability?

- Satisfy our customers
- Understand our processes
- Prioritize areas for quality improvement
  - variation reduction activities
- Verify that process improvements are successful
- Track improvements over time
- Give us information to set realistic tolerances
- Help us identify how to cost products
- Select the best qualified supplier
- Improve our company Bottom Line

Process Capability Studies

Definition

- Process Capability refers to the capability of a process to consistently make a product (outputs) that meets customer specifications.

- Capability Indices are used to predict performance of a process by comparing the width of process variation to the width of specification tolerances.

- Higher level indices include a ‘centering’ calculation
**Process Capability Roadmap**

1. **Select Characteristic**
2. **Study Scope**
   - Short-term - Long-term
3. **Understand**
   - Confidence Interval (based on sample size)
4. **Measurement Capability?**
   - Improve
   - Poor
   - OK
5. **Is Process Stable?**
   - Improve
   - No
   - Yes
6. **Is Data Normal?**
   - Improve / Transform
   - N/A
7. **Multiple Sources?**
   - Segregate / Understand
   - Yes
   - No
8. **Cpk / Ppk Acceptable?**
   - Improve Process
   - OK
   - No
   - OK
9. **Maintain the Gain**

**Key Characteristics**

**What is Important**
- to End Customer
- to Manufacturers
- to Company Operations
- to Supplier Operations

**Identifying Characteristics**
- Design FMEA
- Early Supplier Involvement
- Process FMEA
- White / Black Diamond Designation
  - ◊
  - ♦
Key Process Characteristics

- Mother Earth
- Materials
- Man
- Measurement
- Machine
- Methods

Performance vs. Requirements

Requirements
- Customer Specifications
- Internal Operating Control Levels
- Compare Performance to Requirements
Normal Curve – Area Under the Curve

Normal Curve

- Accounts for Common Cause variation – 99.97%

Process Capability Ratios

Voice of The Customer

Voice of The Process

Capability Ratio:
comparison of the capability of a process to the specification limits

Voice of the Customer
Voice of the Process

LSL
USL

Process Range
Specification Range

John Breckline – Key Quality
Cowtown Quality Roundup - 2018
Short-Term / Long-Term

Process Capability

How it’s measured

- $C_p$ – capability index
- $P_p$ – performance index
- $C_{pk}$ – ratio to the smallest value (USL/LSL)
- $P_{pk}$ – ratio to the smallest value (USL/LSL)

$$C_p = \frac{USL - LSL}{6s}$$

$$C_p = \frac{\text{Total Tolerance}}{\text{Process Spread}}$$

$$C_{pk} = \min\left(\frac{\bar{X} - LSL}{3s}, \frac{USL - \bar{X}}{3s}\right)$$

$$C_{pl} = \frac{\bar{X} - LSL}{3s} \quad \text{or} \quad C_{pu} = \frac{USL - \bar{X}}{3s}$$
The Sources of Variation

- Machine
- Measurement
- Customer Satisfaction
- Environment
- Man
- Material
- Methods

Process System

Process Capability

Long Term vs. Short Term Variation

- Mother Earth
- Materials
- Man
- Measurement
- Machine
- Methods

5 Min Variation
Short Term

10 Hr Variation
Long Term

6 Mo Variation
Performance
**Measurement**

Measurement Systems Analysis (MSA)
- Gage Repeatability & Reproducibility (GR&R)

**Variable GR&R**
- Understand capability of measurement
  - Percent of Contribution – Variance
  - Percent of Study – Std Dev
  - Percent of Tolerance (P/T Ratio) ****
  - Effect of sample selection
- <10% acceptable
- 10-30% marginal
- >30% high risk

**Variable Gage R&R**

\[
\sigma^2_{\text{total}} = \sigma^2_{\text{product}} + \sigma^2_{\text{measurement system}}
\]

Observed Variability = Product Variability + Measurement Variability
Basic Statistics... Distributions

Distributions:
- Not all distributions are Normal
- Exponential Distribution is common for one-sided specs
  - Flatness – PPB – many other
- Predictive statistics require Normal Distributions

Central Limit Theorem

Concept
- The sample mean become normally distributed as sample size increases
- The spread of the sample means are less than the spread of the individuals of the sample

Value
- Non-normal distributions can be assessed using normal distribution statistics and tools (Cpk, SPC, etc.)
- Most inferential statistical tools assume normality of data
  - Confidence Intervals
  - SPC / Control Charts
Understand Your Process

Long Term Process Capability

Tool Wear Direction
Suggested Monitoring

Locating Slot Width
Upper Crush Rib
Lower Crush Rib
Snap Height
Assembly Features

Upper Spec
Lower Spec

Nom-
X
Suggested Monitoring

Process Capability Roadmap

Select Characteristic

Study Scope
Short-term - Long-term

Understand Confidence Interval (based on sample size)

Measurement Capability?

Is Process Stable?

Is Data Normal?

Multiple Sources?

Cpk / Ppk Acceptable?

Is Process Stable?

Maintain the Gain

Improve / Transform

Improve Process

Improve

Poor

OK

N/A

OK

No

Yes

OK

No

Yes

No
Conducting Capability Studies

Preparation:
– Select ‘critical to customer’ characteristics
– Assure validity of specifications
– Assure capability of measurement system (GR&R & P/T)
– Assure process stability at time of study – document
– Study Run / Data Collection (sampling plan)
  • Process Potential – 30+ Consecutive Pieces
    – Cannot truly calculate Ppk or predict long term performance
  • Short Term Study – n=5 for a day (20 groups of n)
    – Ppk statistics used to predict long term performance
  • Long Term Study – extract data from ongoing SPC
    – Cpk and Ppk values will effectively be the same – actual long-term

Analysis / Action:
– Process data – include specification
– Check stability – run chart analysis
– Check normality – visual, probability plot, statistic
– THEN
– Determine Cpk & Ppk as appropriate
  • Must understand process conditions and limitations
  • Ppk is an estimate
– Determine actions to improve or maintain
Stability

If common causes of variation dominate, the output of a process forms a distribution that is stable and predictable over time.

Metric = Lines on Time

If special causes of variation dominate, the output of a process is not stable over time and not predictable.

Metric = Lines on Time

Stability & Normality

Stability

– Without stability, cannot use data as a predictor of future
– Special Causes create instability – removal for study?

Normality:

– Calculations are based on Normal Distribution
– Further from ‘normal’ less accurate → totally invalid
– Calculation Tests (p-value) & Probability Plotting
Minitab Capability Sixpack

Process Capability Sixpack for Thickness

Is it in control? (stable)

Is it Normal?

Is it in control? (stable)

How does the process variation compare to the spec limits?

What do the last 25 groups look like?

Last 25 Subgroups

Capability Plot

Minitab Capability Summary

Process Capability Analysis for CO2-Long

USL

LSL

Cpm

Overall Capability

Observed Performance

Exp. “Within” Performance

Exp. “Overall” Performance

Pp 1.58  PPM < LSL  0.00  PPM > USL  0.00  PPM < LSL  0.02
PPU 1.33  PPM > USL  0.00  PPM > USL  0.00  PPM > USL  0.05
PPL 1.84  PPM Total  0.00  PPM Total  0.00  PPM Total  0.07
Ppk 1.33
**Process Capability**

Process Capability rule of thumb:

- Cpk > 1.50 Process is Six Sigma
- Cpk > 1.00 All Product Meets Requirements
- Cpk = 1.00 Most Product Meets Requirements
- Cpk < 1.00 Some Product Does Not Meet Requirements

- Ppk typically 0.33 less than Cpk

What are YOUR standards for Cpk?
What is difference between Cpk & Ppk in YOUR PROCESSES?

Note: Above calculates take in 1.5 σ shift of mean over time

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**Process Capability**

Objective of Process Capability Analysis

- Determine how the natural process limits compare with the specification range
- Depending on the comparison to standard:

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Study Outcome

Do nothing -1-
-2- Change the specs
Center the process -3-
-4- Reduce process variability
-5- Accept the losses
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John Breckline

Retired but...
Motorola: Auto Electronics, Commercial, Telecom (pagers)
Nokia: MBB / Continuous Improvement Manager
AT&T: MBB – Transactional / Lean Projects
ASQ Certifications: CQE (87), CBB (03), CSQP (17)
Certification Preparation Instructor since 1997
30+ years in Quality Disciplines
- Inspection, Sampling, Data Systems
- SPC, Measurement, Supplier Quality
- Quality Systems Management
- Six Sigma Master Black Belt

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