Short Run SPC
PMPA Technical Conference

Pit Stop Indy
Tune Up Your Team

April 8, 2014

Gary K. Griffith

Corona, California
Gary K. Griffith

- 44 Years Exp.
  - Automotive
  - Aerospace
  - Education
    - Engineering
    - Manufacturing
    - Quality
- Technical Book Author
  - Quality
  - Engineering
  - Shop Technical
A Process

Operator, Machine, Method, Materials, Measurements, Environment

- All processes vary, all the time
- No two parts or lots are ever alike

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Processes Vary

- Variation
  - Common Causes
  - Special Causes
- Tolerances
  - Specifications - what we want!
  - Natural - what the process will do!

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Three Causes for Defective Output

Variation is out of control

Process Setup off target

Process is not capable

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Case Study
“Ugly Parts”

- Machine Shop
  - Screw Machines
- Ugly Parts on Shelf
  - Sales Affected
  - Competitors Parts Look Better
- Miscellaneous Dimensional Problems constantly cause rejections

**Machine Shop Root Causes:**
- Tool Wear
- Speed Rate
- Feed Rate
- Cut Depth
- Power Surge

**Effects:**
- Dimensional Problems
- Various Dimensions
- Poor Surface Finish

**Solution:**
- SPC on Surface Finish

Surface finish is a key response variable that identifies root causes quickly

When surface finish was brought into control, dimensional problems went away and suppliers parts made his competitors’ parts look ugly.

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Value Steam Case Study
“Sprung a Leak”

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Over/Under Adjustments

- **Over-adjustment**
  - Adjusting (changing) a process when it does not need adjustment
  
  Variability is exploded when over adjusting processes

- **Under-adjustment**
  - Not adjusting (changing) a process when it does need adjustment

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Rules for Short Run SPC

- Focus on the **process**, not part numbers
- It must be the **same process** stream
- Look for **families** of products within common traits
- Use **coded data**
- Statistical charts require **20 subgroup** samples of data (not part numbers)
- Variation in different parts within a family must be **representative**
- Measurements must be made to a fine enough degree to **detect variation**

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
# Product Families

<table>
<thead>
<tr>
<th>Family</th>
<th>Process</th>
<th>Similarities</th>
<th>Differences</th>
<th>Key Characteristic</th>
<th>Chart / Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
<td>Extrusion Press</td>
<td>All Tubes, all Aluminum, Same Tolerances</td>
<td>Nominal Diameters</td>
<td>Outside Diameter</td>
<td>Target $\bar{X} - R$</td>
</tr>
<tr>
<td>Part</td>
<td>Press</td>
<td>Same part, Same Tolerances</td>
<td>3 Different Materials</td>
<td>Height</td>
<td>Target $\bar{X} - R$ One for each material</td>
</tr>
<tr>
<td>Spindle</td>
<td>Drill Press</td>
<td>Drilled Holes, Same Material</td>
<td>4 Spindles, Different Sizes and Tolerances</td>
<td>Inside Diameter</td>
<td>Target $\bar{X} - R$ One for each spindle</td>
</tr>
<tr>
<td>Part/Material</td>
<td>Roll Forming</td>
<td>All Aluminum, Same Tolerance</td>
<td>Nominal Heights</td>
<td>Height</td>
<td>Target $\bar{X} - R$</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Mill</td>
<td>All Steel, Same Dimension, Same Tolerance</td>
<td>Nominal Sizes</td>
<td>Depth</td>
<td>Target $\bar{X} - R$</td>
</tr>
<tr>
<td>Cutter Path</td>
<td>N/C Lathe</td>
<td>Diameters cut by same tool, same machine axis, same cutter path</td>
<td>Nominals and Tolerances</td>
<td>Diameters</td>
<td>Target $\bar{X} - R$ Largest diameter furthest from chuck jaws</td>
</tr>
</tbody>
</table>

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
“Key” Characteristics

- **Key Product**
  - Fit, Form, Function, Reliability

- **Customer Exciter**
  - Good = Highly Pleased Customer
  - Bad = Loss of Contract

- **Response Variable**
  - Output variables affected by the process

- **Key Path Variables**
  - Processing Type, machining Type

- **Process Control Variables**
  - e.g. temperature, time, speed, feed, etc.

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Control Planning Process

1. REQUIREMENT
   - Customer
   - Internal
   - Objective(s)

2. PRODUCT
   - Type
   - Order Qty
   - Families?
   - Material

3. CHARACTERISTIC(S)
   - Key Product
   - Key Process

4. PROCESS
   - Type
   - Cycle Time
   - Adjustable?

5. CONTROL METHOD
   - Chart Type

6. SAMPLE SIZE / FREQUENCY

7. MEASUREMENT METHOD
   - Tool
   - Method
   - Discrimination

8. GAGE R&R
   - Preparation
   - Study

9. CAPABILITY STUDIES
   - Initial Cpk

10. TRAINING
    - Per Control Plan

11. CONTROL

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
A Process Control Plan

DoRight Mfg. Co.

<table>
<thead>
<tr>
<th>Process: Lathe</th>
<th>Part name: Input shafts</th>
<th>Part no.: All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next assembly: Pilot housings</td>
<td>Prepared by: J. Smith</td>
<td>Approved by: H. James</td>
</tr>
<tr>
<td>Team leader: K. Samuels</td>
<td>Title: SPC facilitator</td>
<td>Title: Mfg. manager</td>
</tr>
</tbody>
</table>

Control characteristics


(1) Two different charts (one for aluminum shafts and one for steel shafts)

Process control plan

<table>
<thead>
<tr>
<th>Control characteristics</th>
<th>Measurements</th>
<th>Process variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Char.</td>
<td>Specification limits</td>
<td>Statistical method</td>
</tr>
<tr>
<td>A</td>
<td>Various</td>
<td>Target avg. and range $(N = 0)$ ( (1) )</td>
</tr>
<tr>
<td>B</td>
<td>Various</td>
<td>Target avg. and range $(H = 0)$ ( (1) )</td>
</tr>
</tbody>
</table>

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Short Run Control Charts

- **Benefits**
  - Fewer Charts to Maintain
  - Improvements affect all families involved
  - Process control is continuous
  - Control methods focused on the process
  - Part number information can always be obtained

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Use Coded Data

- Data can be coded
  - Nominal = 0
  - Historical Ave. = 0

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>NOMINAL</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>20224-1</td>
<td>.750</td>
<td>± .020</td>
</tr>
<tr>
<td>34520-2</td>
<td>.250</td>
<td>± .010</td>
</tr>
<tr>
<td>48028-4</td>
<td>.500</td>
<td>± .005</td>
</tr>
</tbody>
</table>

**Table 3.2: Coded Measurements**

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>NOMINAL</th>
<th>ACTUAL MEASUREMENT</th>
<th>CODED MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>20224-1</td>
<td>.750</td>
<td>.753</td>
<td>+.003</td>
</tr>
<tr>
<td>34520-2</td>
<td>.250</td>
<td>.249</td>
<td>-.001</td>
</tr>
<tr>
<td>48028-4</td>
<td>.500</td>
<td>.500</td>
<td>0</td>
</tr>
</tbody>
</table>
Target Chart
Nominal = 0

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
### If Process is Not Adjustable

#### Historical Targets

<table>
<thead>
<tr>
<th>SPECIFICATION TARGET</th>
<th>HISTORICAL TARGET</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>.500 Nominal Dimension</td>
<td>.502</td>
<td>Process is not easily adjusted, and .502 is an acceptable output target for the product.</td>
</tr>
<tr>
<td>63 Max. Surface Finish</td>
<td>30 finish</td>
<td>The output is best described as low is best and the existing output finish (30) is being obtained without extra effort.</td>
</tr>
<tr>
<td>.100 Min. Wall Thickness</td>
<td>.175 Wall</td>
<td>The output is best described as high is best and the existing output wall (.175) is being obtained without extra effort.</td>
</tr>
</tbody>
</table>

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
## Target Chart

### Historical = 0

<table>
<thead>
<tr>
<th>Part #</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>B</th>
<th>C</th>
<th>C</th>
<th>D</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data 1</td>
<td>57</td>
<td>59</td>
<td>28</td>
<td>31</td>
<td>24</td>
<td>22</td>
<td>36</td>
<td>61</td>
</tr>
<tr>
<td>Sum 2</td>
<td>59</td>
<td>60</td>
<td>30</td>
<td>29</td>
<td>21</td>
<td>20</td>
<td>42</td>
<td>58</td>
</tr>
<tr>
<td>Rate</td>
<td>116</td>
<td>119</td>
<td>58</td>
<td>60</td>
<td>45</td>
<td>42</td>
<td>78</td>
<td>119</td>
</tr>
<tr>
<td>Rate</td>
<td>58</td>
<td>59.5</td>
<td>29</td>
<td>30</td>
<td>22.5</td>
<td>21</td>
<td>39</td>
<td>59.5</td>
</tr>
<tr>
<td>Range</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Range</td>
<td>60</td>
<td>60</td>
<td>30</td>
<td>30</td>
<td>24</td>
<td>24</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Range</td>
<td>-2</td>
<td>-0.5</td>
<td>-1</td>
<td>0</td>
<td>-1.5</td>
<td>-3</td>
<td>-1</td>
<td>0</td>
</tr>
</tbody>
</table>

### Averages

- **UCL** = 3.74
- **CL** = -1.2
- **LCL** = -6.1

### Ranges

- **UCL** = 8.58
- **CL** = 2.63
- **LCL** = 0

---

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Variation Within Family Must be Representative

Monitor the Range Chart

- Look for patterns after a new setup, such as
  - Trends
  - Runs
- This is a signal
- Do the Range Test

\[
\frac{\overline{R}_{SUSPECT}}{\overline{R}_{ALL}} \leq 1.33
\]

HIGH RUN

\[
\frac{\overline{R}_{ALL}}{\overline{R}_{SUSPECT}} \leq 1.33
\]

LOW RUN

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Out of Control Patterns

Nelson’s Tests

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Shift Happens
Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Trend Pattern
Process Corrected

UPWARD TREND ON AVERAGES

INDIVIDUALS

AVERAGES

RANGES

Group range: Selected (1-6,11-20)
Auto drop : ON
CL Ordinate: 3.000
Curve: Johnson Su.
K-S: 0.209
Cpk : 1.25  Cp : 1.77
AVERAGE(m) : 9.887
PROCESS SIGMA : 0.380

TREND: TOOL WEAR

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Cycles Pattern

AVERAGES

RANGES

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Outlier

Chart: X-bar R Chart: SAMPLE9 - TIR

O.D. GRINDER

AVERAGES

0.0
0.3
0.6
0.9
1.2
1.5

PCL

LCL

RANGES

0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

RBAR

LCL

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Two Universes

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
“Hugging” Pattern

AVERAGES

Ranges

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Flatline

Chart: X-bar R Chart: TOCFLAT - PATIENTS

FLAT LINE PATTERN

AVERAGES

Hardness Averages

-4 0 4 8 12 16 20 24

PCL=9.553

LCL=-2.422

UCL=21.528

RANGES

0 4 8 12 16 20 24

LCL=0.000

UCL=20.803

RBAR=6.368

LCL=0.000

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Process Capability

A process is capable when:

- It is in control
- The individual measurements are normally distributed
- The variation of the process lie comfortably within specifications

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Indy 500

Capable

Not Capable

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
The Normal Distribution (Bell Curve”)

A Predictable Process
A Centered & Capable Process

<table>
<thead>
<tr>
<th>Cp</th>
<th>1.49</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cpk</td>
<td>1.37</td>
</tr>
</tbody>
</table>

Histogram

- File: CLASS7
- Units: INCH
- Target: 0.24000
- LSL: 0.23700
- USL: 0.24300

BORE I.D. 0.2400 +/- 0.003 DIA.

08/19/93 12:31 Page 1 of 1
A Capable Process

CASA BLANCA - LINEAR DIM.  
A CENTERED AND CAPABLE PROCESS

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Capable but Off Center

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Operator Changed Dies
(No one knew?)

<table>
<thead>
<tr>
<th>CELL BOUNDARY</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4130</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.4140</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.4150</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.4160</td>
<td>24.0</td>
<td>18.0</td>
<td>12.08</td>
</tr>
<tr>
<td>0.4170</td>
<td>20.0</td>
<td>14.0</td>
<td>9.06</td>
</tr>
<tr>
<td>0.4180</td>
<td>16.0</td>
<td>10.0</td>
<td>6.04</td>
</tr>
<tr>
<td>0.4190</td>
<td>12.0</td>
<td>6.0</td>
<td>3.02</td>
</tr>
<tr>
<td>0.4200</td>
<td>8.0</td>
<td>2.0</td>
<td>-3.02</td>
</tr>
<tr>
<td>0.4210</td>
<td>4.0</td>
<td>0.0</td>
<td>-6.04</td>
</tr>
<tr>
<td>0.4220</td>
<td>0.0</td>
<td>0.0</td>
<td>-9.06</td>
</tr>
<tr>
<td>0.4230</td>
<td>0.0</td>
<td>0.0</td>
<td>-12.08</td>
</tr>
<tr>
<td>0.4240</td>
<td>0.0</td>
<td>0.0</td>
<td>-15.10</td>
</tr>
</tbody>
</table>

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Short Run SPC Capability Study

Part A ±.030
Part B ±.020
Part C ±.015
Part D ±.010

Nominal

Std. Dev. = .001”

<table>
<thead>
<tr>
<th>Process $\bar{X}$</th>
<th>Process $\sigma$</th>
<th>Part number</th>
<th>Coded nominal</th>
<th>Coded tolerance</th>
<th>$C_p$</th>
<th>$C_{pk}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.002</td>
<td>.001</td>
<td>123-1</td>
<td>0</td>
<td>±.010</td>
<td>3.33</td>
<td>2.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>789-3</td>
<td>0</td>
<td>±.015</td>
<td>5.0</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1011-4</td>
<td>0</td>
<td>±.020</td>
<td>6.67</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1213-5</td>
<td>0</td>
<td>±.030</td>
<td>10.0</td>
<td>9.33</td>
</tr>
</tbody>
</table>

Ref: Statistical Process Control for Long and Short Runs 3rd Ed. Griffith Training
Questions?

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