



Plastics Topics – SPC essentials

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Process Topics – SPC essentials

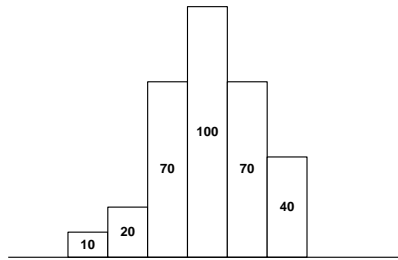
Contents:

Part 1: Process capability	2
Part 2: Establishing control charts for variables	4
1. The range chart.....	4
2. The average chart.....	5
Part 3: Using and analysing control charts for variables	6

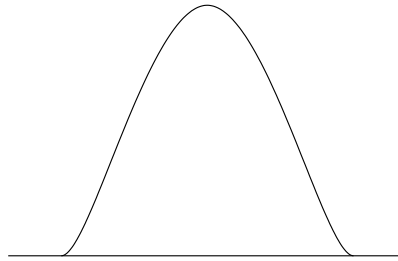
Process Topics – SPC essentials

Part 1: Process capability

- Before starting to use statistical process control it is necessary to determine if the process is 'capable' of producing within the specified tolerances. This requires a 'Process Capability Study' to be carried out.
- Select 50 samples from a continuous run of product.
- Measure the desired feature and plot results in a histogram using 6 bars.



- If the distribution is a normal distribution, then proceed.



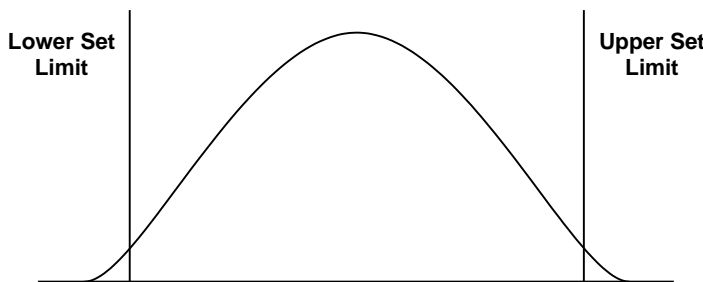
Note: If the distribution is not a normal distribution, then other techniques are needed.

- Calculate the mean (\bar{X}) and the standard deviation (σ) for the 50 results using a standard calculator or a spreadsheet.
- Estimate the process variability (relative to the specified tolerances) from the formula:

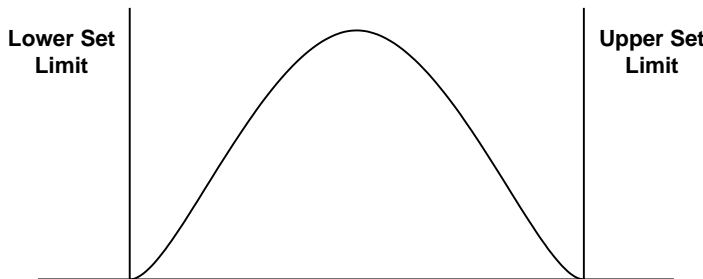
$$C_p = \frac{USL - LSL}{6\sigma}$$

USL = Upper Set Limit or Upper Acceptable Tolerance.
LSL = Lower Set Limit or Lower Acceptable Tolerance.

- This value is a measure of the 'process spread'. If C_p is < 1.00 then it will not be possible for the process to produce parts within tolerance. When C_p is > 1.33 the process is said to be 'capable'.

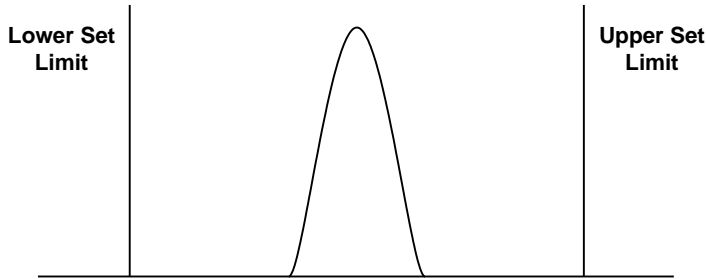


C_p is less than 1.00
The process is centred on the tolerances but it will never be possible to produce all the parts inside the tolerance.



C_p is equal to 1.00
It will be possible to produce 99.73% of the parts inside the tolerances but only if the process is exactly centred on the tolerance band and does not vary.

Process Topics – SPC essentials



C_p is greater than 1.33
 The process spread is less than the tolerances. It will be possible to produce all the parts inside the tolerances even with process variations.

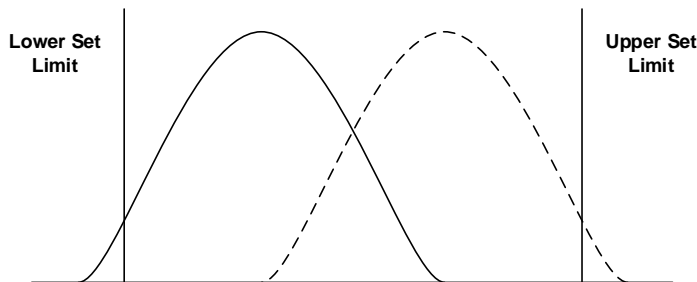
- C_p only describes the spread; it does not describe the location and even with a small spread (C_p > 1.33) it is possible to produce out of tolerance parts. We need to be able to describe the location of the curve, this is done as follows:

- Calculate Z_{UPPER} and Z_{LOWER} from the formulae below and find the smaller of the two:

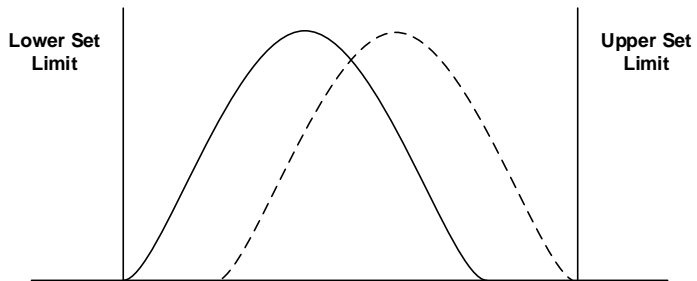
Z_{min} is the smaller of $Z_{UPPER} = \frac{USL - \bar{X}}{\sigma}$ and $Z_{LOWER} = \frac{\bar{X} - LSL}{\sigma}$.

$C_{pk} = \frac{Z_{min}}{3}$,

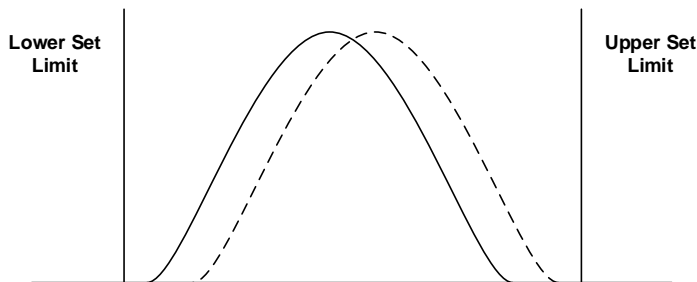
- As with C_p, if C_{pk} is less than 1.00 then it will not be possible for the process to produce parts within tolerance. When C_{pk} is > 1.33 the process is said to be 'capable'.



C_{pk} is less than 1.00
 The process location is outside the tolerances. It will not be possible to produce all the parts inside the tolerances.



C_{pk} is equal to 1.00
 The process location is inside the tolerances but close to the limits. It will just be possible to produce all the parts inside the tolerances.



C_{pk} is greater than 1.33
 The process location is well inside the tolerances. It will be easily possible to produce all the parts inside the tolerances.

- The values for Z_{UPPER} and Z_{LOWER} can be used with P_Z tables to calculate the proportion of the output that will be beyond the specification limits.

Process Topics – SPC essentials

Part 2: Establishing control charts for variables

1. The range chart

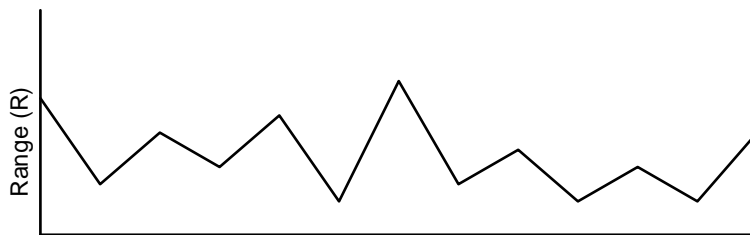
- Using a running and stable process:

Take 5 samples from the process each hour. Record the average (\bar{X}) and the range (R – the difference between the highest and lowest measurements) for the set of 5 samples.

Continue until 25 sets of data are available.

- Range Control Charts

Plot the results for the range (R) on a preliminary Control Chart as below:



- Calculating the control limits for R:

Find the average of the 25 values for R. This is \bar{R} and $\bar{R} = \frac{\text{Sum of R values}}{25}$

The control limits are given by

- Lower Control Limit for R: $LCL_R = D_3 \times \bar{R}$
- Upper Control Limit for R: $UCL_R = D_4 \times \bar{R}$

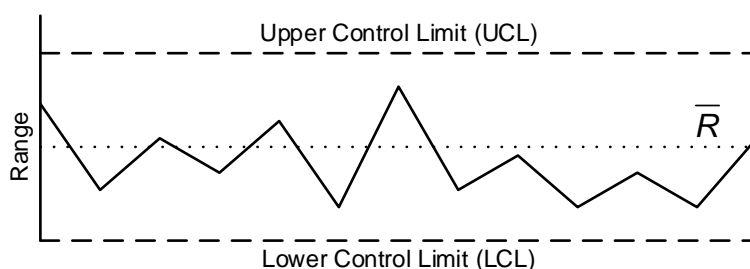
Where D3 and D4 are constants that vary with the sample size as below:

Sample Size	2	3	4	5	6	7	8	9	10
D3	0	0	0	0	0	0.08	0.14	0.18	0.22
D4	3.27	2.57	2.28	2.11	2.00	1.92	1.86	1.82	1.78

For a sample size of 5 (see Step 1) the Control Limits are then

- Lower Control Limit for R: $LCL_R = 0$
- Upper Control Limit for R: $UCL_R = 2.11 \times \bar{R}$

- Plot the average for the range (\bar{R}) and the Upper and Lower Control Limits (UCL_R and LCL_R) on the Control Chart:



- Interpret the Range Control Chart for control (see Sheet 3).

Process Topics – SPC essentials

2. The average chart

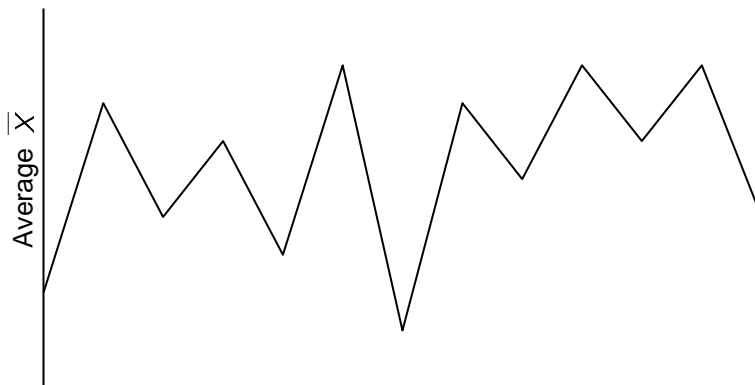
- Using a running and stable process:

Take 5 samples from the process each hour. Record the average (\bar{X}) and the range (R – the difference between the highest and lowest measurements) for the set of 5 samples.

Continue until 25 sets of data are available.

- Average Control Charts

Plot the results for the average (\bar{X}) on a preliminary Control Chart as below:



- Calculating the control limits for \bar{X} :

Find the average of the 25 values for \bar{X} . This is $\bar{\bar{X}}$ and $\bar{\bar{X}} = \frac{\text{Sum of } \bar{X} \text{ values}}{25}$

The control limits are given by

- Lower Control Limit for \bar{X} : $LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \times \bar{R}$

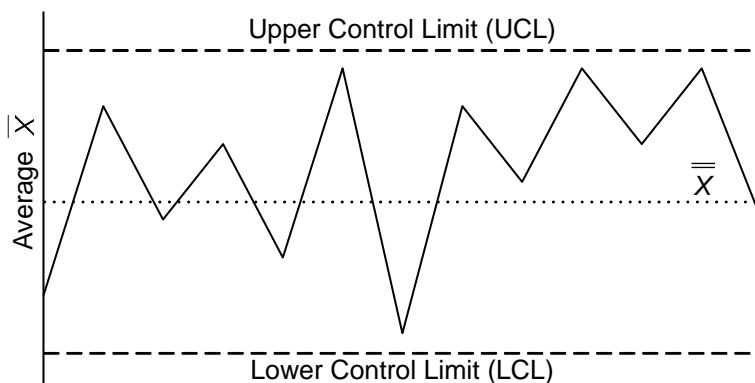
- Upper Control Limit for \bar{X} : $UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \times \bar{R}$

Where A_2 is a constant that varies with the sample size as below:

Sample Size	2	3	4	5	6	7	8	9	10
A_2	1.88	1.02	0.73	0.58	0.48	0.42	0.37	0.34	0.31

Use $A_2 = 0.58$ for a sample size of 5 (see above) and calculate the Control Limits.

- Plot the average of the averages ($\bar{\bar{X}}$) and the Upper and Lower Control Limits ($LCL_{\bar{X}}$ and $UCL_{\bar{X}}$) on the Control Chart:

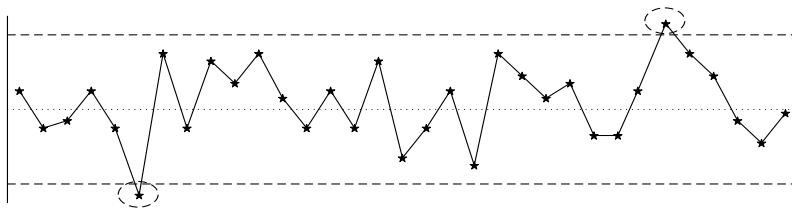


- Interpret the Average Control Chart for control (see Sheet 3).

Process Topics – SPC essentials

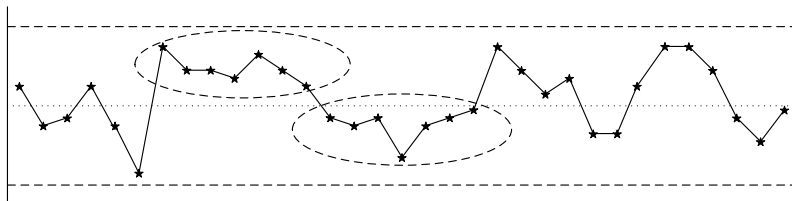
Part 3: Using and analysing control charts for variables

- Use the previously created Control Charts (see Part 2) with the Average and the Upper and Lower Control limits marked on them.
- Measure 5 samples every hour and calculate:
 - The average of the 5 measurements (\bar{X}).
 - The range of the 5 measurements (R).
- Plot \bar{X} and R on the relevant Control Chart during the production run.
- Interpret the Range Control Chart first, look for any of the following patterns:
 - No points outside the control limits (upper or lower):



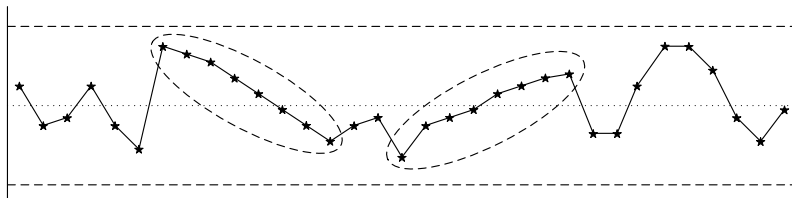
Points outside the control limits show 'special events' have occurred and 'out-of-control' parts were made.

- No run of 7 consecutive points above or below the average line:



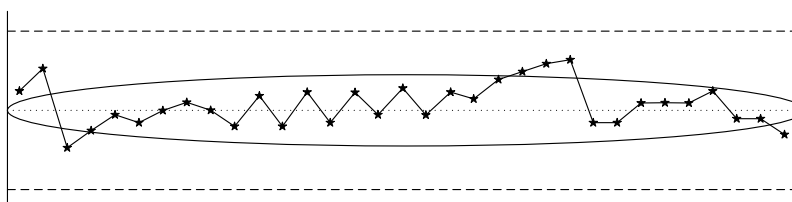
There is a step change in the process. Check for new materials or similar changes.

- No run of 7 consecutive points upward or downward:



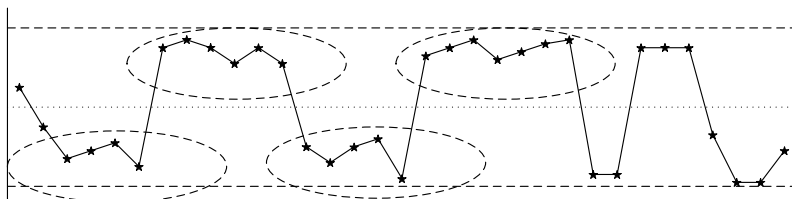
The process is drifting upwards or downwards. Check for tool wear or similar gradual changes

- No pattern with 2/3 of the points in the middle 1/3 of the control limits:



The process is too consistent, check and recalculate the Control Limits.

- No pattern with 2/3 of the points in the outer 2/3 of the control limits



The process may have internal variations. Are two tools being used and has the output been mixed up?

- If any of these patterns are present then the process is out of control for the range. Investigate for special causes and correct as required.

Process Topics – SPC essentials

- If the Range Control Chart is in order, then interpret the Average Control Chart:

Look for the same patterns in the Average Control Chart as in the Range Control Chart:

- No points outside the control limits (upper or lower)
 - No run of 7 consecutive points above or below the average line
 - No run of 7 consecutive points upward or downward
 - No pattern with 2/3 of the points in the middle 1/3 of the control limits
 - No pattern with 2/3 of the points in the outer 2/3 of the control limits
- If any of the patterns is present then the process is out of control for the average. Investigate for special causes and correct as required.
 - Important Points for using Control Charts
 - Operators should carry out the measurements and record them on the chart themselves – this is not to be done by 'Quality Control', it is an operator task.
 - Operators should join the recorded and calculated points together with a straight line to the previous result.
 - Operators should always initial and date the Control Chart when they make the measurements.
 - Operators should always record significant events (materials batch changes, operator changes, colour changes etc) on the Control Chart – it makes finding the special causes easier to find and rectify.
 - Control Charts are working documents, not works of art.
 - Unless the Control Chart indicates one of the above patterns then the process should never be adjusted by the operator. Parts are being produced in tolerance and the process is in control – there is no need for adjustment.
 - Hint: To drive this home, make adjusting the machine without a Control Chart warning a disciplinary offence.
 - Do not be in a rush to adjust the machine – always study the process carefully before making any adjustments to the machine.
 - Control Charts provide a 'common language' for operators, managers and reporting. They are the glue that holds a factory together.
 - Control Charts can be used to detect 'special causes' these can be fixed or eliminated by local action.
 - The detection and elimination of 'common causes' (the reason for the Upper and Lower Control Limits) is generally much more difficult. Eliminating 'common causes' generally requires management action and possibly even investment in the process.