The use of Control Charts with Composite materials

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Control Charts

- Everything varies at least a little bit. How can you tell when a process is just experiencing normal variation versus when something out of the ordinary is occurring? Control charts were designed to make that distinction.

Line graph for Fill Compression ETW
Example Control Chart

X-bar Chart for Fill Compression ETW

CTR = 72.53
UCL = 76.34
LCL = 68.72
Why use a control chart?

• It’s as important to know when to leave things alone as it is to know when to take action. Control charts tell us when we need to take action and when to leave the process alone. It does this by distinguishing between “common cause” variation inherent to the process and “special cause” variation due to some change in the process.
Interpreting Control Charts

- As long as all points lie inside the upper and lower control limits, the variation is presumed to be normal or common cause variation.
- When a data point falls outside those limits, it is termed an ‘out-of-control’ point and is considered to be due to ‘special cause’ variation. It indicates that it’s time to look at the process and figure out what might have caused the change.
Interpreting Control Charts

• An Out-of-Control point signifies that an investigation needs to be made to determine the cause. Action should be taken to ensure that the process returns to a stable state.

• The probability of a ‘false alarm’, a point lying outside the control limits due to random chance alone is set at 0.3%.
Problems with traditional Control Charts

• Composites require extensive testing. Creating and analyzing dozens of different control charts for each batch may not be the best approach.
  - It’s time consuming to create and interpret so many charts.
  - While each chart only has a small probability of a ‘false alarm’, using many different charts can increase the probability of such ‘false alarms’ to unacceptable levels.
Multivariate Control Charts

- Different measurements can be combined into a single chart, eliminating the need for all those different charts and reducing the number of ‘false alarms’.

![Multivariate Control Chart](image)

- UCL = 27.48
Why use a multivariate control chart?

• It combines measurements from many different characteristics into one control chart.

• Correlated characteristics are handled appropriately. Changes that affect more than one characteristic will be noticed faster.

• Only one chart is needed to make an initial assessment of whether the process is performing consistently or a change has occurred.
What type of Multivariate Charts should be used?

Recommend the Hotelling T² control charts

- Charts both subgroup means and variance
  (Only the means charts are being shown in this presentation)
- Independence of variables is not required
- Off the shelf software is available
  Statgraphics™ was used to create all charts shown in this presentation
Control Charts for Composites

Multivariate Control Chart

UCL = 27.48

This a $T^2$ control chart for 10 different tests combined together:

- 90° ETW Compression
- 90° ETW Tension
- 0° ETW Compression
- 0° ETW Tension
- Al Shear ETW
- 90° RTD Compression
- 90° RTD Tension
- 0° RTD Compression
- 0° RTD Tension
- Al Shear RTD
What does an Out-of-Control point signify on a multivariate chart?

- The process has changed in some way
- Find out which characteristic(s) was affected.
  - Use control ellipses for two or three variables at a time to identify the problem area.
  - Use traditional single variable control charts if appropriate
- Develop a plan to correct the process based on what characteristics have been affected and what the suspected cause is.
Control ellipses are used to evaluate the joint variation of two or three variables. These can be used to identify problem areas.
Now that the problem area has been identified, a traditional X-bar chart shows the problem.
Plotting the data against the Agate Acceptance Criteria show no problem with the material.

**Compression 90 RTD with Spec Limit**

Spec Limit 95.78
Nominal 100.68
Plotting the data against the Agate Acceptance Criteria show no problem with the material.

Individual Values plotted with Spec Limit

Nominal: 100.68
Spec Limit: 80.86
Advantages of Control Charts

• The acceptance limits are computed using AGATE method.
• If the Coefficient of Variation is unrealistically low for the qualifying material, it may be adjusted according to the following guidelines approved by the FAA last year:
  – Below 4%, set at 6%
  – Between 4% and 8%, set to $\frac{1}{2} \times \text{C.V.} + 4$
• In this situation, since the co-efficient of variation was adjusted up from 5.05% for the spec limit, the out-of-control point is still within tolerance. Thus, the manufacturer can respond to the problem PRIOR to any out-of-spec product being produced.
Potential Difficulties with Multivariate Control Charts

• The control chart does not identify which characteristic(s) have caused a point to fall outside the control limits. This must be assessed separately.

• If more than one characteristic has contributed to a point being out-of-control, how should the process be adjusted and monitored to account for all characteristics affected?

We will be investigating different approaches to deal with these issues.