EXPERIENCES OF STATISTICAL PROCESS CONTROL AT BP GRANGEMOUTH

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INTRODUCTION

This article outlines a procedure for implementation of a large scale industrial statistical process control (SPC) system. Figure 1 illustrates the type of univariate SPC chart that was the outcome. The chart has warning and action limits that were sensitive to episodes of disturbance but which accommodated periods of normal running.

The high density polyethylene (HDPE) plant at the Grangemouth site of BP Amoco Chemicals was a challenge because it needed numerous SPC charts for the melt index (MI), one for every HDPE grade. The issue was to ensure the charts had consistent performance from grade to grade.

LARGE SCALE SPC IMPLEMENTATION

Data mining: A data base archive was mined to select episodes of normal running for every HDPE grade. A selection threshold in engineering units was unsatisfactory for plant-wide application because it would be different for different grades and it was hard to ensure consistency. Our approach was to apply to all grades the same production-oriented measure, which was the percentage of time the plant was disturbed. If the plant manager assessed the plant to be disturbed 20% of the time (including grade change-overs) then the outcome of data mining would be to classify the 20% worst episodes as disturbed. The remaining data (the reference set) would represent normal operation.

Selection of chart limits: The SPC chart performance metric is the rate of false alarms when the process is running normally. A formula based on probabilities exists for the average run length (ARL) between false alarms during normal running (Wetherill and Brown, 1991; BS 5700). An SPC chart based on BS5700 uses warning limits at ±2σ and alarm limits at ±3σ. The ARL of such a chart is 320 for a Gaussian distribution, but the ARL is sensitive to the probability distribution.

The use of percentile limits ensures that all charts have a consistent ARL even when, as in this case, the distribution is not Gaussian. Figure 2 shows probability plots for the reference sets of two HDPE grades and indicates the procedure. For grade B, for instance, the 99.9% alarm limit is at a melt index value of 50 and for grade A it is at an MI value of 1.4.

One can use tighter chart limits to give the benefit of earlier detection of disturbances, but at the cost of a higher rate of false alarms. Percentile limits offer the flexibility to maximise chart sensitivity subject to an acceptable false alarm rate. For instance, if a false alarm every four days is acceptable (ARL=24 with two samples per shift) then the ARL formula indicates that action limits at 2% and 98% and warning limits at 4.2% and 95.8% should be used (Thornhill et. al., 1999).
The table below shows that the ARLs were close to target when the percentile limit method was applied to the SPC charts. The last column shows that the BS5700 ±2σ and ±3σ limits gave ARLs that were not near the value of 320 expected for a Gaussian distribution, nor were those ARLs similar for the two grades. The ±2σ and ±3σ limits led to off-target and inconsistent chart performance, while the chart limits selected by the percentile methods gave on-target and consistent ARLs.

<table>
<thead>
<tr>
<th></th>
<th>Target ARL</th>
<th>Actual ARL</th>
<th>Target ARL</th>
<th>Actual ARL</th>
<th>Actual ARL with ±2σ and ±3σ limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>grade A</td>
<td>320</td>
<td>324</td>
<td>24</td>
<td>24</td>
<td>70</td>
</tr>
<tr>
<td>grade B</td>
<td>320</td>
<td>306</td>
<td>24</td>
<td>26</td>
<td>122</td>
</tr>
</tbody>
</table>

**USER EXPERIENCES**

Data mining and selection of chart limits occupied the bulk of the project time. Software written for the project procedure gave recommendations for routine grades and freed time for grades that are hard to make and special grades with tight specifications. For those grades the plant manager and the engineers made changes to the recommended chart limits based on their experience and judgement.

Implementation of the SPC system on the plant computer was straightforward once chart limits had been selected. It used a standard SPC chart tool marketed by a statistical software provider.

Operator training took two to three months and SPC then went live. The number of manual interventions decreased and so did the disturbances, implying that some of the disturbances before the SPC system was in place had themselves been the result of manual adjustments, probably overcompensation for other plant disturbances.

One change to the SPC system was made later. A field was added to the display screen in which the operator typed the action taken following an alarm, including "no action" in cases when he judged the alarm to be a false alarm. This automatic capture of actions completed the installation.

**CONCLUSIONS**

- The data mining step dominated this SPC project. Installing the SPC charts themselves was not a major task.
- Data mining proceeded in a systematic manner using a production-oriented criterion of normal running that applied to every product grade.
- Charts were designed to give a consistent target performance using limits based on percentiles of the reference data set.
- The recommended BS5700 ±2σ and ±3σ limits gave inconsistent chart performance in this application because the data had a non-Gaussian distribution.

**References**
