Process control takes flight

A technology used in the prevention of in-flight aircraft collisions is also the basis for a user-friendly way of viewing process data, writes **Mike Spear**

In brief

- **GPC (geometric process control) allows operators to find the set of parameters within which the best product is made**
- **The best operating zone is generated from the plant's previous history**
- **Another multivariable problem, pharmaceutical formulation development, lends itself to a similar graphical approach**

In its simplest form, process control involves maintaining a plant's process parameters – pressures, temperatures, flows, concentrations and so on – within defined limits to deliver the desired product specification. The difficulty is in defining those limits. In a multivariable process, changing any one variable can have an effect not only on product quality but also on other variables, not all of which may be under the operator's control. What operators are looking for, says Robin Brooks, managing director of Curvaceous Software, is their process 'sweet spot' – that set of parameters within which they make the best product.

Finding that sweet spot, or operating envelope, is made more difficult by the often large number of variables involved in a typical process. While traditional optimisation techniques like statistical process control (SPC) can analyse plant data mathematically to examine the interrelationships between process variables, product specifications, process yields and the many other key performance indicators, Brooks says they largely fail to define an envelope or a boundary. 'They define more of a fuzzy spot in space where you get good results, but it's indeterminate where the boundaries of that fuzzy spot are.'

What Curvaceous employs is a technology dubbed geometric process control (GPC), which models the operating envelope of a process without any recourse – at least by those using the technology – to the complex maths involved in those traditional techniques. But more than modelling the process envelope, GPC presents it to the viewer in a single picture, complete with all variables and their interactions on show in an easily accessible colour-coded display (see page 22).

'The beauty of it is that the operator display is an inherent part of the model,' explains Brooks, 'there's no maths involved for the users. They see the changing envelope – showing them the interactions of their variables — and know if they stay in the green space they will achieve a good result.' And they know that because the green space, the best operating zone (BOZ), has been generated not from mathematical models or process simulations but from the plant's actual previous history.

In practical terms, the GPC software interfaces with the plant's distributed control system (DCS) through an industry standard OPC interface. Acting as a supervisory, rather than regulatory, control system, it currently runs on a PC, although Brooks says the company may in the future license the technology to DCS vendors to re-implement on their systems. For now, the company is intent on adding to its 85-strong customer base, built up since Brooks first took his ideas to the chemical industry in 2001.

However, the seeds of GPC were sown many years earlier, when Brooks worked with IBM and Exxon in the 1970s to create one of the earliest process historian databases. In those pre-spreadsheet days, engineers had no practical way of extracting much sensible information from the masses of measurements recorded in the historians, and the arrival of the spreadsheet several years later didn't really help to solve the underlying problem.

But in the early 1990s Brooks came across the beginnings of the solution in the IBM work of mathematician Al Inselberg, who had invented a coordinate transformation from n-dimensional space to two-dimensional space and was using it to solve problems geometrically instead of algebraically. His patented solution to the four-dimensional problem of in-flight aircraft-collision avoidance, for example, is used in many of today's aircraft.

Brooks went on to license the coordinate transformation technology from IBM and, with his colleague John Wilson, used it as the basis of the first patented Curvaceous product, the CVE. The first customer in 2001 was Ineos Chlor at Runcorn, Cheshire, where an initial 18-month field trial of GPC was conducted on a large plant at the chloralkali complex. CVE was first used offline on historical operating data to understand past performance and identify possible improvements. From that examination of past data, a BOZ was selected and a GPC model built.

At first the model was used to look at the quality of alarms or operator alerts on the plant. Many plants have alerts set too high or too low because of uncertainties over exactly where their process envelope should lie. Using its GPC model, at the first attempt Ineos reduced the number of false alerts from 49% to less than 10% of the total generated. And that 10% has since been reduced further by improving the choice of variables in the envelope.

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When Ineos Chlor later introduced GPC into the control room in operator advisory mode, process efficiency improved 2% in the first three weeks — equivalent to a gain of £700 000 a year. According to Brooks, GPC has now been tested in open loop control on several other plants and been shown to work very well. But, in such a supervisory mode, 'you are dependent on the operator doing exactly what you are asking him to do [via the GPC display]', he says, explaining why some of the company's current development work is focused on closed loop control versions for fully automatic process control — work that has attracted the sponsorship of some major oil companies and 'will lead to a field trial very shortly'.

Another area of control that Curvaceous is interested in is batch processing. As Brooks points out, the main difference here from the continuous processes of the likes of Ineos

Chlor and the oil refiners, is that 'you have to include time as a process variable'. This approach has now resulted in what he describes as 'the first ever model-based control system for the batch process industries that works across many variables simultaneously — not just an ideal trajectory for one of them, which has been the state of the art until now.'

The first batch model is now being evaluated by agrochemicals producer Syngenta at its plant in Grangemouth, Scotland, during manufacture of the fungicide active ingredient oxystrobin. The company's operations manager, Ian Williamson, says he initiated the project 'to identify relationships in production processes that we believed existed but hadn't been able to validate using a statistical approach'.

The first phase of the project last year involved overcoming the initial hurdle of merging data collected from different sources over several months and hundreds of batches with real-time data from the batch processes. This required new software routines to interrogate the time-based data so that the starts and stops of the different stages of the process could be identified automatically by the GPC system. 'But now we're in a position where it's relatively straightforward to pull all the data together,' Williamson says. His longer term vision is to 'move to a stage where we have CPM, the modelling tool, actually live on the plant to help the operators control the process'.

The project is now in its second phase, with Syngenta's chemists, process engineers and shift managers starting to use CVE. With a strong background of using statistical tools to analyse process data, Williamson says: 'one of the attractions for me in taking CVE forward, is that people can relate to pictures. You don't have to understand complex maths or statistics.'

That's not to say all his chemists, process engineers and plant operators immediately saw the attraction. 'One of the difficulties,' he reflects, 'is not to allow people to be dominated by what they think they know about the process. You need an enquiring mind, but it is fairly easy to see the relationships in the pictures presented by CVE. It's an interesting, different approach — to look at geometric shapes rather than values. But I think if you use real data that people are familiar with on a day to day basis, they pick it up much faster and almost immediately can interpret and get value from the pictures.'

Another Curvaceous customer, Phil Plumb, a senior scientist with AstraZeneca R&D in Charnwood, Leicestershire, makes a similar point. 'Because you're not used to looking at parallel coordinate plots, it does take a bit of practice, but once you get your eye in, the packages are easy to use and relatively easy to interpret.' Plumb uses CVE and another package, CRSV (Curvaceous Response Surface Visualiser), not for process control but in pharmaceutical formulation development. Like process control, this too is a multivariable problem — with interactions between ingredients, processing conditions and product properties — that lends itself to the graphical approach of CVE for identifying an optimum formulation.

'Geometric process control models the operating envelope of a process without any recourse to the complex maths involved'

Apart from its steadily growing customer base, Curvaceous Software has also been gathering industry awards at an impressive rate. The first in 2003 was the European Process Safety Award for its alarm system work with Ineos Chlor, followed in fairly rapid succession by innovation awards from the IChemE (the 2005 AMEC Award), the Chemical Industries Association (the 2006 Innovator of the Year) and the IET's 2006 Innovation Award for Manufacturing. Evidence, perhaps, that the traditionally conservative chemical industry is beginning to see the bigger picture offered to it by such a radically new technology.

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Tools of the trade

Curvaceous visual explorer

The Curvaceous Visual Explorer (CVE) uses the technique of n-dimensional geometry to allow any number of variables 'n' to be displayed on a two-dimensional graph. Just as a single point, say p1, in three-dimensional space can be represented orthogonally as x1, y1, z1, so a single data point in 'n' dimensions can be represented in parallel coordinate geometry as a single polygonal line joining the values of all the variables for that one point.

By feeding historical and real-time data from the process into CVE and displaying it on this one graph, plant operators can now compare hundreds, even thousands, of process runs and see instantly where the best operating conditions occurred (Figure 1). And because all operating parameters, product specifications, and in fact any other relevant data can be included in a CVE display, the operators can select operating points to satisfy whatever criteria they want: product quality, yield, optimum energy usage, emissions levels etc.

This set of satisfactory operating points effectively defines the process envelope, or best operating zone (BOZ). GPC basically aims to keep the plant operation within the BOZ, which it does through another of the company's products, the Curvaceous Process Modeller (CPM). This turns the data mining operation of CVE into one of real-time process control by calculating limits on each variable that will keep it in the BOZ (shown by the green lines in Figure 2) for the current values of all the other variables.

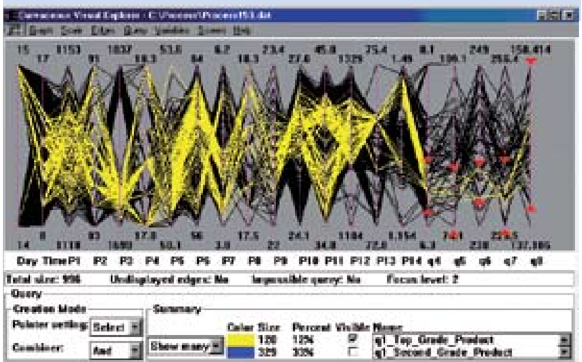

Figure 1 (top): The quality specifications for top-grade product are shown as red triangles, with all lines passing through all these 'top spec' areas coloured yellow, from which the process envelope can be derived

Figure 2 (below): A typical CPM operator display indicating the Best Operating Zone (in green) and actual process data points (blue dots). If an operating point moves outside of the BOZ, the CPM generates advice on how to move it back inside