Turned off by teaching

Myke King wonders why we are still not properly teaching process control to chemical engineers

AGREED, this issue is by no means as important as agreeing the cause of global warming or other challenges to the chemical engineering profession – such raising the status afforded to engineers by society. But revising the way that we teach process control to chemical engineers is becoming increasingly important. Too many are graduating with little knowledge relevant to the process industry and most leave university with the view that it is a highly mathematical subject understood by few.

Ziegler and Nichols, when developing the controller tuning method now taught to most chemical engineers, were members of the ASME Control Systems group. Those familiar with the method will know it involves adjusting the controller tuning parameters until a sustained oscillation is achieved. When their paper was first distributed to other members of the group, their initial reaction was to have it withdrawn from publication. They claimed that it was impossible for a process to oscillate. They had reached this conclusion from the study of the movement of a mass suspended from a damped spring! It took almost a year before the argument was resolved and the authors permitted to publish their paper in 1942.

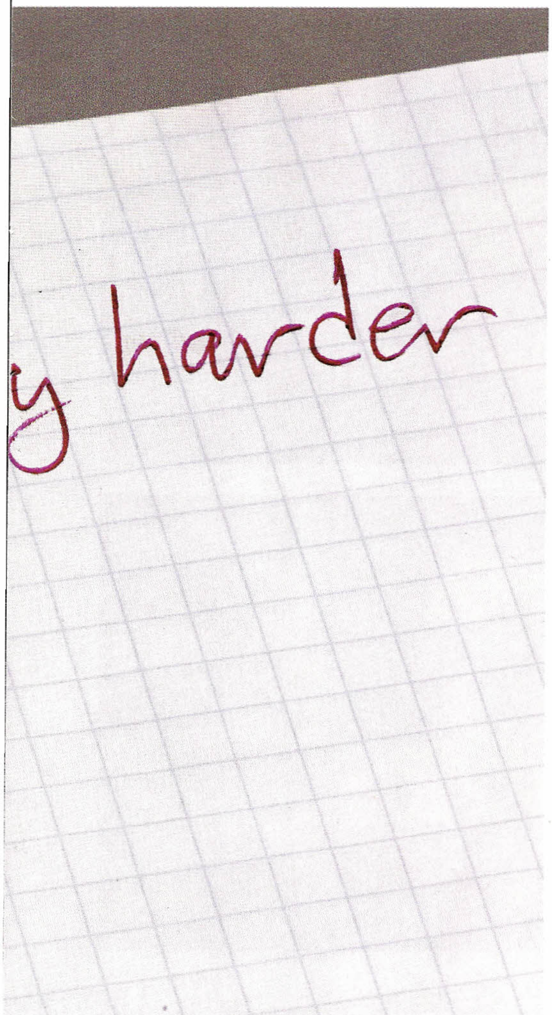
mechanical roots

Since then, process control has moved rightly into the remit of chemical engineering but much remains of its roots in mechanical engineering. For example, process-control courses still teach Bode plots. For those who had long since stopped paying attention in their process-control lectures, these describe how a process responds if a sinusoidal disturbance is introduced. The plots show the effect that the frequency has on attenuation and phase lag – all very useful if you want to know how your car's suspension will behave when you drive over corrugated steel at different speeds. However, it's not particularly relevant to how a chemical plant might behave. Similarly, the diagrams developed by Whiteley and Nyquist are even less understood and have even less value. We also mustn't forget the contribution made by Pierre-Simon Laplace; he is responsible both for the Laplace Transform and for the numerous undergraduates who abandoned the subject of process control when the mathematics became too daunting. To be fair, his transforms are very valuable in describing the way that processes and controllers behave but, for undergraduates, there are alternative approaches using mathematics more readily understood.

> "too many are graduating with little knowledge relevant to the process industry"

greater potential

In the time of Ziegler and Nichols, the view was that process instrumentation was necessary but costly. Plants were designed with the minimum of measurements – just enough for safety and operability. Much of the instrumentation was local to the process and almost all the controllers were single loop. Now processes are much more extensively instrumented, with most of it in the control room. The instrumentation has become 'smarter', supporting a wide range of features such as linearisation, alarms, self-diagnostics and networking. The control buildings have become more sophisticated with blast-proofing, climate control and ergonomic design. The control systems have



progressed from local and panel-mounted controllers to distributed control systems (DCS) with operator consoles and links to supervisory control computers and data-collection systems. Data from other sources such as the laboratory and product storage are increasingly integrated with the control system. Sophisticated control applications based in the DCS and using multivariable predictive control (MPC) packages are now commonplace. Rigorous, equation-based, closed-loop optimisers are installed on a wide range of processes. As a result, the proportion of plant construction costs attributable to process control has risen from less than 5% to around 25%. One would question whether the attention paid to teaching control to chemical engineers has risen in proportion.

what is the cost?

So what is this costing industry? A large number of very talented chemical-engineering graduates choose not to enter the control-engineering profession because of the poor image that theoretical courses create. Indeed, on graduating, the current chairman of IChemE's Process Measurement and Control Subject Group had no ambitions in this direction but, on his first day, was prevailed upon by his employer to join the process-control section. He is one of many who discovered, by chance, that the practical application of process control bears little relationship to its theoretical counterpart and can be one of the more rewarding branches of chemical engineering. Not surprisingly he is now championing efforts to make university process-control lecturers reconsider their course content.

Those who do follow a career in process control can find themselves working in an organisation managed by a chemical engineering graduate who has no appreciation of what the technology can do and its importance to the business. Consider the following scenario where a key piece of process equipment has failed. By authorising costly overtime, paying premium prices for spare parts and using expensive air freight the repair is completed 24 hours sooner. Assuming such an event occurs annually, capacity utilisation has been increased by about 0.3%. Would the same manager authorise similar expenditure to improve by 15% the performance of an advanced control scheme that can achieve a continuous 2% increase in capacity utilisation? Both have the same effect on production. If not, then not only has the manager missed the opportunity to significantly improve profitability but probably now has a demotivated control engineer looking for transfer to a more valued role.

Returning to Ziegler and Nichols, we should challenge why their tuning method, after 70 years, is still the most popularly taught. While there are workarounds which avoid the hazardous approach of deliberately causing process oscillation, the control algorithm for which it was developed is no longer in common use and the tuning results in adjustments to the process that are far too aggressive. In practice, nobody uses the method. Perhaps its value is as a benchmark to make newly published methods look good. A survey conducted in 2000 found 235 published tuning methods, but every one of these has a serious flaw – as do most of the tuning software packages on the market. It is not surprising that most tuning is performed by trial and error. This is time consuming and rarely results in an optimally tuned controller. It is costing the process industry millions in terms of the manpower it consumes and the losses incurred by the resulting poor process performance. The industry is rife with myths

> "the Laplace Transform is to blame for the numerous undergraduates who abandoned the subject of process control"

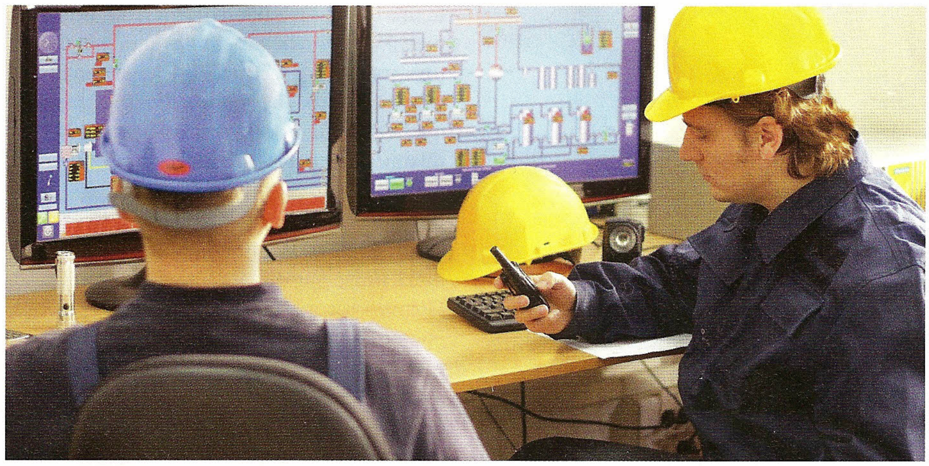
$$\mathcal{L}\{f(t)\}$$

about the best version of the control algorithm, the use of derivative action and how controller performance is assessed. It is time for universities to address this – both in course content and in providing hands-on experience through laboratory exercises. While the cost of the instrumentation is likely to make impractical performing such exercises on the real equipment, computer simulations are now trivial to develop and would provide the same experience. Such exercises would help the student better understand process dynamics, learn how they can be obtained from plant tests, experiment with different control algorithms and confirm that the tuning method works well.

the rise of MPC

In the 1980s industry began the move to MPC. Until then, so-called advanced regulatory control (ARC) was configured using the block-building structure of the DCS or developed as custom software. While this often resulted in extremely complex schemes that needed a lot of maintenance, it did foster the development of control-engineering skills. MPC changed all this. Suppliers convinced customers that engineers no longer needed to understand control engineering. It also became clear that many process control strategies would not be feasible without MPC. There is now no doubt that MPC has boosted the profits for companies around the world but there is a growing view in the industry that it has been taken too far. There are examples of schemes involving around 150 process variables. Such controllers have reached the point where it becomes almost impossible for the process operator to understand the adjustments a scheme makes and why. The profession is beginning to revert to simpler designs, often moving functionality from the MPC down to the ARC layer. The problem is that, when MPC replaced most ARC applications, the expertise in MPC similarly displaced the expertise in ARC. Many of the engineers who were active in this field at the time have since retired or moved into other roles. Re-establishing this expertise will be the main bottleneck in re-establishing the technology.

The use of MPC will nevertheless rightly remain widespread. Control engineers and their contractors invest thousands of man-hours in the necessary plant testing and commissioning. Improving the basic controls is not usually an option once MPC is in place. This would likely change the process dynamics and would thus involve substantial re-engineering of the MPC. Thus, poor basic control remains the status quo and becomes the accepted standard to the point where it is not addressed even when the opportunity presents itself. Most would see the logic of ensuring the basic control layer is effective before implementing MPC but few give this more than the minimum of attention. They are content that the basic controls respond to the changes made by the MPC; rarely does the project team rigorously assess what might be achieved by improving them further.



know what can be measured

Chemical engineers are taught little about instrumentation. While instrument engineering is a subject in itself, chemical engineers need an appreciation of what is measurable. Instinctively they know that there are devices that measure simple parameters such as flow, temperature and pressure, but what do they know of on-stream analysers? It is now possible to measure virtually any stream property. There is also a huge demand for inferential properties; these use basic measurements to infer properties for which on-stream analysis is too costly, too slow, too unreliable or where the technology simply doesn't exist. The development of such techniques is quite definitely in the realm of chemical engineering and their value to the industry is immense.

theory vs practice

Some argue that it is not the role of universities to teach practical skills. Indeed it is the case that many valuable control technologies were developed by engineers applying the theory they learnt at university. There is a place for much of the theory – particularly in disciplines such as aeronautical engineering where exploring stability by experimenting with the real thing is somewhat frowned upon. In chemical engineering only a small minority of undergraduates need it. The theory would be better included in a follow-on degree, in much the same way that Partnership in Control and Automation Training (PACT) – an alliance of Newcastle University in the UK and a group of companies in relevant industries – does in its MSc. If the universities don't teach practical techniques then the responsibility falls on the process industry. Certainly the industry is good at providing vendor-specific training in the mechanics of configuring the DCS and, similarly, how to design and install MPC. However, the industry is very bad at showing new recruits how to get the best out of basic controls and how to apply ARC techniques. Such expertise is relatively rare and can be more valuably applied to rapidly generate increased process profitability. It is not surprising, then, that this is seen as taking priority over training others. Some companies do take the view that training is in their long-term interest but this is barely enough to sustain the current low level of expertise. There would also appear to be a reluctance in the process industry to train its employees to the point where they will be head-hunted by specialist implementation companies. If the universities don't take the lead here then nobody will.

> *"some argue that it is not the role of universities to teach practical skills"*

the case for change

For the universities to change what they teach is no simple matter. Lecturers well versed in practical application are relatively rare. They already try to familiarise themselves with industry through sponsored research work, secondments, attending conferences and contact with practitioners through organisations like IChemE's subject groups. PACT has taken a step further by bringing in visiting lecturers from industry to work alongside academic staff. If it works for MSc students then why not for undergraduates? There are certainly many in industry who would welcome the involvement. After all, it is in the industry's interest to have graduates better informed about what the subject truly entails and so attract more good-quality engineers to the profession. Further, industry would benefit from engineers who can hit the ground running in terms of specifying and implementing effective control schemes. **tce**

Myke King is author of the recently published book *Process control: A practical approach* and founder of process control specialist Whitehouse Consulting. Previously he was managing director of KBC Process Automation and head of the process control section at ExxonMobil's Fawley refinery