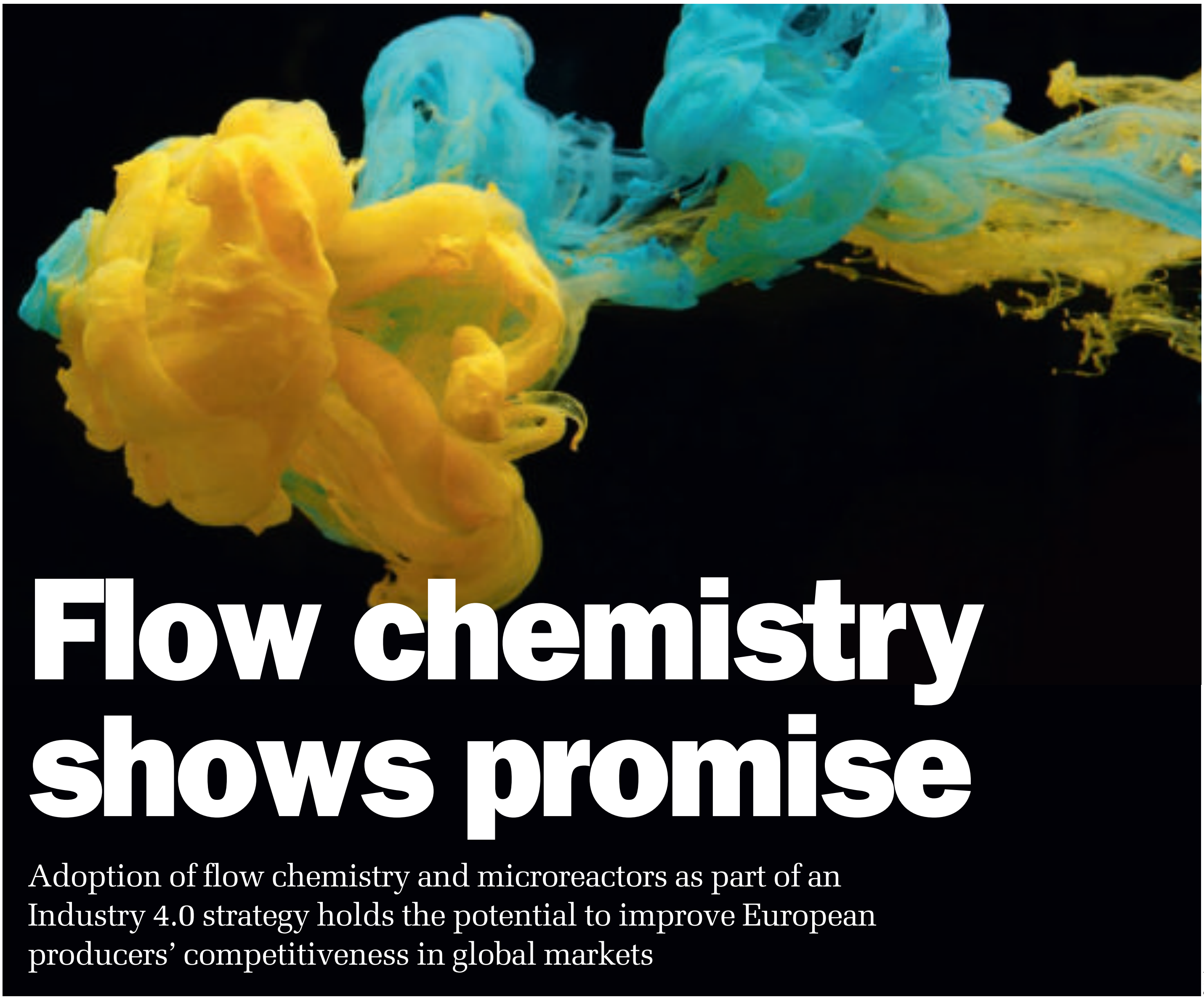

Flow chemistry shows promise

Adoption of flow chemistry and microreactors as part of an Industry 4.0 strategy holds the potential to improve European producers' competitiveness in global markets

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JOHN BAKER LONDON

Chemical producers in Europe are faced with two huge challenges: to maintain competitiveness in global markets while hampered by feedstock disadvantages and energy and environmental costs; and retain global market share, as output and demand growth in most other regions exceeds that in home markets.

A recent study by Roland Berger Strategy Consultants, "Chemicals 2035 – Gearing up for growth", predicts that Europe's chemicals output will expand by at most 1.5%/year between now and 2035, with most of this taking place in downstream, high value-added segments, such as agrochemicals and engineering plastics.

Europe's share in global markets will slip from 19% today to just 13%, a far cry from the 33% figure enjoyed in 2000.

Recognising this, companies are beginning to challenge business models and look for alternative paths for development, says Neil Checker, a partner at Roland Berger. As a part of this "companies are beginning to think through their strategies for technology and engineering management."

These functional areas have not attracted much attention previously. But in recent years, "producers have been looking at their assets and company set-up to drive efficiency and effectiveness," he explains.

DRIVERS FOR CHANGE

This is as much a response to the changing situation that companies find themselves in, as it is to the search for competitiveness. Checker identifies several drivers: the long-term trend towards operating facilities outside Europe – in Asia and the US – but still maintaining a centralised engineering base; and the fact that many majors are shifting towards an asset-light or more specialty portfolio, largely through M&A, such as BASF, Dow Chemical and DuPont.

This portfolio shift is leading to requirements for more flexible and agile operations and greater responsivity to the market, as well as lower capital intensity but increased complexity. As a result, he says, "companies need a different set of capabilities in technology and engineering and new ways to run and maintain their assets."

One area that is attracting growing attention is the whole debate around Industry 4.0 and the way digital technologies might be used to bring about potentially fundamental changes in the business – from front-end market intelligence to plant operations and customer interactions, and right across the supply chain.

IDENTIFY KEY ACTIVITIES

But as Checker points out, "integrated end-to-end digital transformation is a potential long-term vision but not a practical or operationally implementable solution in the short or even medium term. Companies need to breakdown their key business and operational activities and identify options as a first step."

Roland Berger has recently focused attention on one area it believes has the capability to make a significant difference in the medium term: process intensification, and more particularly the use of flow chemistry and microreactors.

GOOD FIT WITH INDUSTRY 4.0

Annegret Brauss, a consultant at Roland Berger, explains that flow chemistry fits very well with Industry 4.0 and is already being seen by industry as a hot topic, in areas such as pharma and crop sciences through to specialty chemicals and materials, where batch processes are traditionally used.

"[The technology] offers the potential to move away from large-scale, capital-intensive, centralised production units"

ANNEGRET BRAUSS
Consultant, Roland Berger

The technology, she says, "offers the potential to move away from large-scale, capital-intensive, centralised production units towards much smaller-scale, flexible and distributed production networks". This, she adds, will have associated impacts on the supply chain and logistic set-ups needed to service the market with more specialised, customised products.

The use of flow reaction technology in small-scale reactors delivers a number of benefits. Fluid reactants are brought together in a carefully controlled way through mixing, with the reaction taking place in a small temperature-controlled volume and on a continuous basis.

This leads to improved thermal management, enhanced mixing control and access to larger operating windows in terms of reaction time, temperature and pressure. It also enables the development of safer, more efficient and robust processes, with high yields and lower levels of by-products, and thus reduced need for downstream separation.

Other benefits, points out Brauss, include lower energy use and lower greenhouse gas emissions, and improved logistics, as production can be distributed and reside closer to end use markets. Flow chemistry also allows for shorter development times and thus faster time to market and ultimately reduced costs overall.

The technology, adds Checker, "is a fundamental challenge to the industry, which has traditionally been built on the concept that bigger is better in terms of plant capacity."

Economies of scale have been the management mantra in the past. But now, with geographic and portfolio shifts, he argues that producers need to ask themselves "do we need to challenge this and move to more flexible, smaller plants and manage a more complex infrastructure?"

This will not of course happen overnight – companies are heavily invested in traditional capacity and, outside of bulk commodity products, few products are made using continuous processes. There is thus a shortfall of relevant experience and knowledge in the industry, but one that is being addressed gradually as companies develop expertise with flow chemistry as they scale up from laboratory to industrial scale.

A leading example is being set by DSM, which a few years ago joined with flow chemistry equipment specialist Chemtrix in a collaboration agreement to develop "novel, sustainable production methods". DSM claims to be leader in continuous flow chemistry manufacturing of pharma active ingredients and has commercial scale facilities in Linz, Austria.

DSM is using the technology for a number of reactions, including the Ritter reaction, nitrations and the synthesis of ethyl diazoacetate (EDA), a potentially explosive intermediate, which it then combines with an olefin in a cyclopropanation reaction via carbine formation.

INTEREST ON THE INCREASE

It notes that the use of flow chemistry for process intensification shortens development times, improves productivity and safety, and meets quality and sustainability goals. In the exothermic Ritter reaction unit, for instance, DSM has seen yields of a key monomer increase from 55% to 78%, enabling it to produce 40 tonnes/day.

But it is by no means the only company looking at the technology, although most attention at the moment is at the development scale and large-scale application is still in its early days. Brauss points to companies such as DuPont, Lonza and Velocys as companies actively engaged in flow chemistry development, and there are others such as Dow Chemical and Syngenta which are looking to it for synthesis of active compounds in crop protection products.

On the microreactor side, there are several active suppliers of equipment and expertise, including Chemtrix, originally founded at Hull University in the UK but now based on the Chemelot industrial park in the Netherlands, ThalesNano in Hungary, and Syrris of the UK.

The ICIS Innovation Awards in recent years have seen several microreactor innovations win awards, including Velocys, which has developed microchannel reactors for Fischer-Tropsch reactions that can produce biofuels from syngas, and NiTech in Scotland, which has commercialised continuous flow reaction reactors and crystallisation technology at laboratory, pilot plant and manufacturing scale.

However, the field really is still in its infancy in commercial terms, says Checker. Flow chemistry is being considered as an option when exploring new chemical routes or when safer and/or cleaner processes are required. The technology is becoming accepted in pharma and agrochemicals areas, and fine chemicals, where small production volumes are required.

Given that most producers are heavily committed to batch production and have extensive plants in place, it is unlikely they will scrap this and switch over rapidly.

"There has to be a good business case and companies will apply elements of continuous processing technologies during the shift to smaller, modular and flexible facilities when there is a tangible payoff."

In the longer term, Checker believes flow chemistry processes will ultimately lead to simplified distributed manufacturing, enabling on-site and on-demand production, as part of producers' moves to implement Industry 4.0-type automation and business strategy.

"Companies need a different set of capabilities in technology and engineering and new ways to run and maintain their assets"

NEIL CHECKER
Partner, Roland Berger

As the Roland Berger "Chemicals 2035" report argues: the chemical industry is on the verge of a new age – Chemicals 4.0 – "which will be all about the optimised use of resources and feedstock, process intensification, digitisation of the industry and a focus on adding value to the customer."

Flow chemistry and microreactors might well play a significant role in this new era. But, Roland Berger warns: "playing wait-and-see will rob Europe's chemical industry of the chance to avoid falling further behind Asia and, ultimately, North America too…

"Only those companies that see and embrace the journey ahead as a learning process will one day understand – and reap – the full benefits." ■