PROCESS TECHNOLOGY & AUTOMATION

CHEManager INTERNATIONAL

1/2017

Engineering
Industrial Plant Manufacturing, Asset Modernization, Chemical Process Equipment, Field Network Engineering, Operational Excellence

Automation
Digitalization Strategies, Big Data Analysis, Industry 4.0, Internet of Things, Operational Certainty, Process Alarm Management

Process Technology
Flow Chemistry, Continuous Manufacturing, Modular Production, Pharmaceutical Engineering, Innovation in Manufacturing

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Chemical Engineering – Key to Innovative Production Processes

The chemical and related industries are in a phase of rapid evolution. Many new technologies are being developed motivated by improved chemistry, enhanced safety, low energy consumption and environmental benefits, low inventories, capital cost reduction, novel or enhanced products and value to customers.

In order to respond to today's economic demands as well as to remain competitive, the chemical and related industries have to satisfy the market requirements from intermediate high bulk chemicals to new specialties and active material chemical products, as well as the social and environmental constraints of industrial processes.

In the complex and multi-dimensional environment of modern manufacturing operations, it is a challenge to identify the best manufacturing approach for a specific product, taking into account financial, product- and process-related issues, including globalization of manufacturing, regulatory requirements, company-specific strategies and preferences, and a complex process development environment.

But how can modern process engineering contribute to assure competitiveness and sustainability in the chemical and related process industries?

Given today's leading-edge capabilities, it's reasonable to envision a data-driven factory of the future where all internal and external activities are connected through the same information platform.

Industry 4.0 brings together a host of technologies, including the Internet of Things (IoT) and advanced analytics that enable chemical companies to create a smart supply chain network and factories. It also explores new ways for information to create value. As a consequence of more data generated and stored, data analytics will gain importance.

Chemicals and pharmaceuticals manufacturing will also see more modular concepts allowing a shorter change over time and a higher agility of a factory. This is of special importance for biopharmaceutical products and underlines the need for excellent engineering. In addition we are seeing a move away from batch processing as the industry embraces continuous manufacturing.

The process industry is the innovation driver of the global economy and pace-setter for numerous industrial sectors. Virtually all global value chains profit in some way from the achievements of chemistry, biotechnology and process engineering.

Dr. Ralf Kempf, Editor-in-Chief, CHEManager International

This edition of Process Technology & Automation features articles and interviews dealing with highly topical developments and technologies that can help the industry to deliver higher-quality, more durable and more reliable products and processes. Enjoy reading!

Dr. Ralf Kempf
Editor-in-Chief, CHEManager International

Content

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Digitalization Stimulates Service Business

The Potential of Industry 4.0 in Large Industrial Plant Manufacturing

In a joint recent study of 2017 the VDMA Large Industrial Plant Manufacturers' Group and MaexPartners analyzed the potential of Industry 4.0 for large industrial plant manufacturing. A previous study released by the same partners in 2015 entitled "Industry 4.0 in Plant Manufacturing — Revolution or Evolution?" was influenced by the increasing digitalization of German manufacturing and engineering companies. The industry has since focused intensely on the topic of digitalization and taken appropriate measures to improve competitiveness.

Dr. Christian Gutsche, MaexPartner

Marc Artmeyer, MaexPartner

Olaf Stecker, VDMA

The study is intended to reveal the impact of changes already made and those still expected in large industrial plant manufacturing. In addition to various digitalization strategies which are constantly being adapted to the continuously changing environment, the current study principally focuses on the prospects of new business models.

For around 10 years the structure of the market for large industrial plant manufacturing has been characterized by a steady increase in the number of vendors and a simultaneous trend to a constant but in some branches even declining project volume. The new competitors in addition to established plant manufacturers from Europe, North America and Japan are mainly general contractors from Asia who have not specialized in a specific technology. Consequently, the balance of power between vendors of large industrial plants and their customers has shifted permanently. The competitive constraints in plant manufacturing have increased significantly and a buyer's market has established itself in numerous segments.

Industry 4.0 Increases Opportunities

The results of the study are in some cases surprising. Plant manufacturers assess the opportunities for their enterprises on the market and in a competitive environment to be higher than they were even two years ago because of the increasing trend to Industry 4.0.

This is true both for the possibilities of increasing sales as well as for reducing costs and saving time during project execution. Increases in sales thanks to new products and services are cited as the greatest opportunity. But also opportunities to increase turnover in existing business models are now perceived to be much stronger than they were even in 2015. At the same time, however, new challenges are also seen: in the opinion of most participants, these are primarily to be found in the expected increased competition from companies outside the industry.

This realization also means that enterprises see a greater individual need for action today than in 2015. Despite this clear view of the realities,

only about half of the participating companies were so far able to decide to actively adopt measures to exploit perceived potentials and to control the risks.

On the topic of digitalization strategies, the industry recognizes the present need for action as being relatively evenly distributed over all organizational and technological fields of work and admits that there is still need to improve its "digital readiness". Plant manufacturers, however, consider themselves to be much better prepared for the challenges of digitalization today than they were 2 years ago. This is true both for their own companies as well as for the industry as a whole.

More Service Orientation

Most of those surveyed intend on following the continuing trend to greater service orientation even if it means making major organizational and technological changes. In general, close cooperation with the customer is expected. The implementation of this strategic realignment in the enterprises, however, is considered difficult. In the course of implementing a digitalization strategy, changes are generally expected in many of the existing services offerings. The main focus is on maintenance offerings and big data analyses.

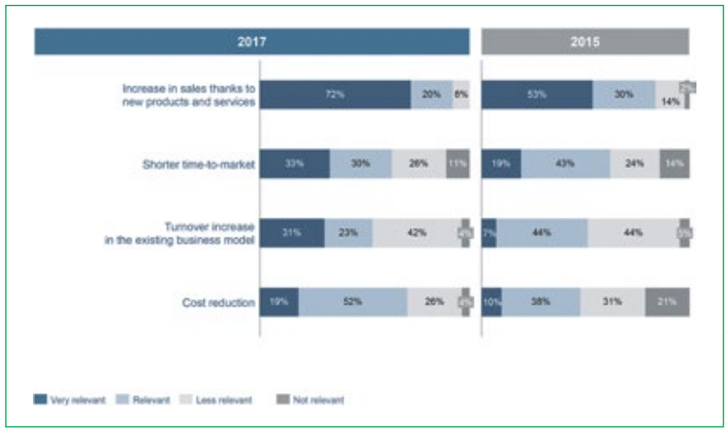
The recorded and analyzed data can be used, for example, to evaluate a plant's condition. The probability and consequences of the failure of individual plant components can thus be determined relatively easily. Using risk assessment, the corresponding maintenance strategy (e.g. run-to-failure, optimization, replacement, etc.) can be deduced and an optimization of the long-term maintenance budget can thus be achieved.

The focus of plant manufacturing is increasingly on the development and use of new business models whose possibilities become more and more clear as digitalization has progressed. This will presumably have implications for the exploitation models and pricing strategies. Exploitation models based on a pay-per-use approach, for example, could be much more in demand in the future.

Digitalization Can Boost Growth

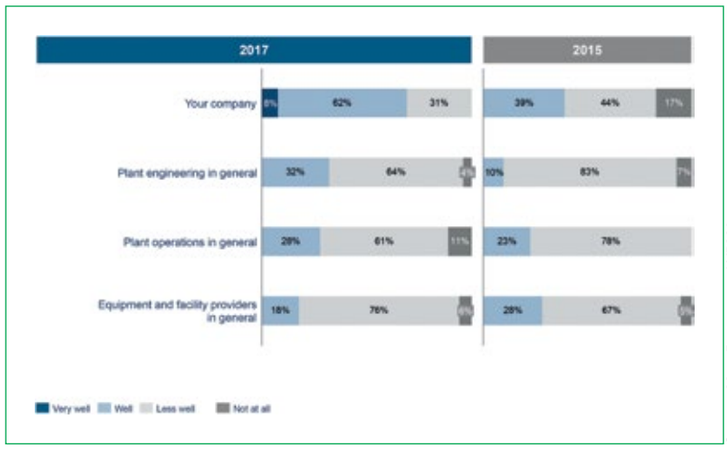
The majority of those who participated in the study at least see good chances of lowering costs as well as for improving turnover and profit through the use of Industry 4.0 technologies. At least 14% of those surveyed expect an increase in profit of more than 10% by 2021 using the existing business model. This value emphasizes the great potential associated with digitalization for further growth in large industrial plant manufacturing.

German large industrial plant manufacturers are in a far better starting position today in regard to Industry 4.0 than in 2015. Today, many companies see great opportunities for using the possibilities digitalization presents especially for developing new strategies in the service business and business models. Enterprises are thus mentally well equipped for the digital change, both operationally and technically. Hence, more and more plant manufacturers are starting to gain access to external knowledge through networking, partnerships and cooperation as well as by purchasing competence.



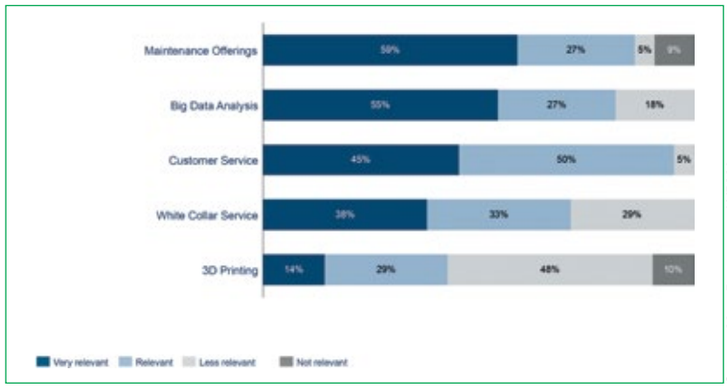
Source: MaexPartners and VDMA

Fig. 1: What opportunities does Industry 4.0 give plant manufacturers?



Source: MaexPartners and VDMA

Fig. 2: How well are plant manufacturers currently prepared for Industry 4.0?



Source: MaexPartners and VDMA

Fig. 3: Where will the principal changes be in existing service offerings?

New Business Models

According to the findings of the study, large industrial plant manufacturers are aware that there is still a further need for action to implement Industry 4.0. The importance of new business models has been clearly recognized as has the threat posed by competitors from outside the industry. The realization that the existing processes and structures developed for today's business models no longer fit in with a digital world and need to be adapted has been admitted by most companies.

Industry 4.0 will not be able to be implemented in plant manufacturing in one giant leap. The previous study from 2015 already showed clearly that it is an evolutionary process. Enterprises also need a definite target vision for implementation. The deduction of an appropriate strategy is thus the order of the day. The business models that are right for a company then follow almost inevitably.

Next Steps to Be Taken

The starting point should be a digital readiness check. Using the insight obtained into relevant processes, structures and technologies during this check, it is possible to identify and rank the priority of the necessary action areas. A corresponding digitalization strategy and the impacts on the business model can be deduced from this test. One focus in this context should be on developing a service strategy. The conditions and knowledge required prior to developing such a strategy are presented in the study in great detail.

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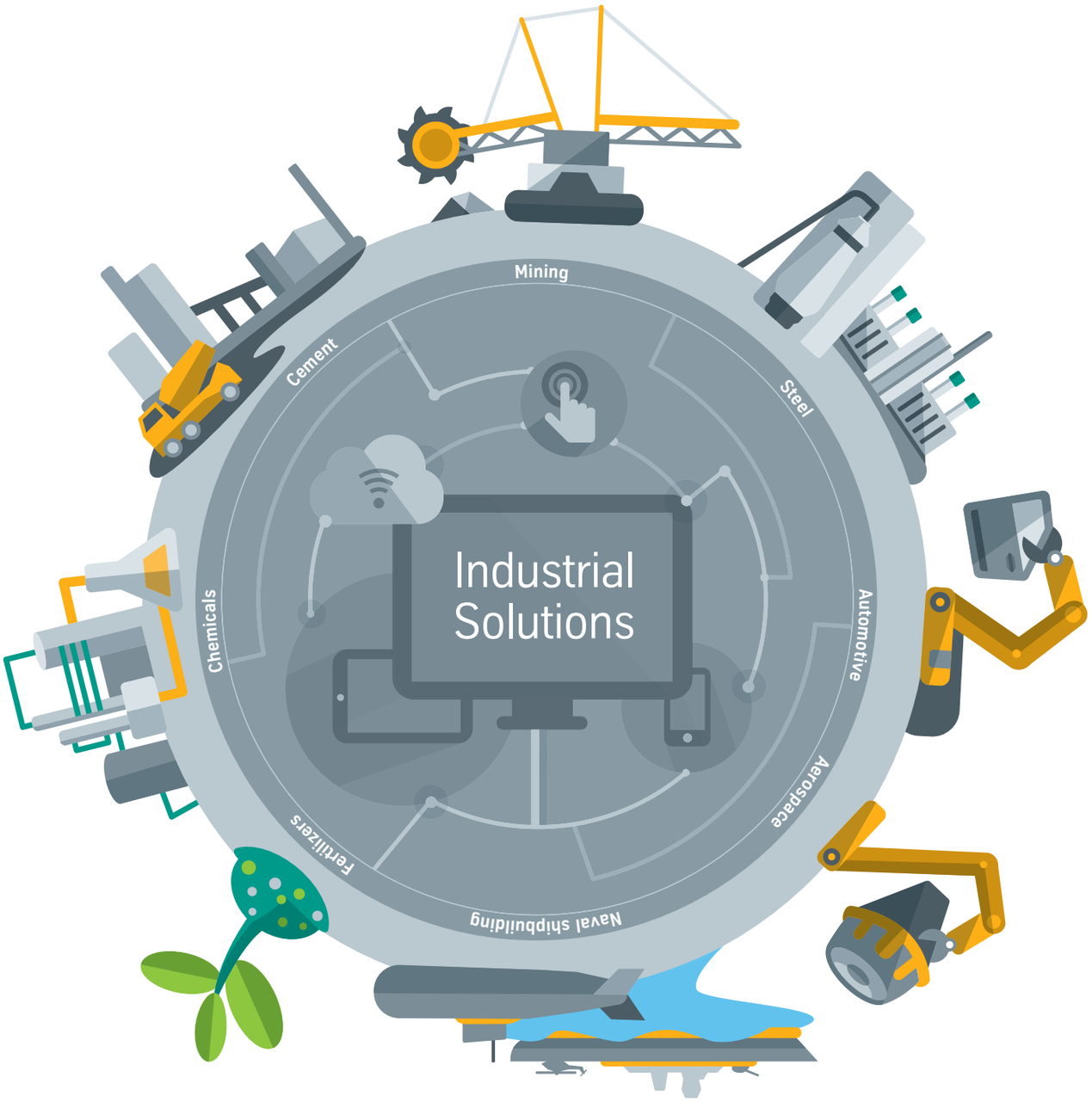
The study is available from the VDMA and MaexPartners.



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Upgrading of the Chinese Chemical Industry

China's Focus on Environmental Protection Provides an Opportunity for Equipment Producers

At a study session earlier this year attended by members of the Political Bureau of the Communist Party of China (CPC) Central Committee, Xi Jinping, the general secretary of the CPC, highlighted the increasing importance of environmental protection in the country. He said the country should protect the environment "like one protects one's eyes" and treat the environment "as one treats one's life."

Dr. Kai Pflug, Management Consulting – Chemicals

Xiao Li, freelance consultant

In fact, this focus on environmental protection, which is also one of the five key points of the current Five-Year Plan (2016-2020), already has a strong impact on China´s chemical industry. But what will confront chemical manufacturers with challenges will open up opportunities for equipment suppliers and service providers. Three aspects are particularly relevant.

Stricter regulation: The laws regulating the allowable emissions of chemical plants are getting stricter, and their scope increases. Costs of releasing pollutants into the environment will increase substantially. In fact, even the European chemical companies active in China seem to feel the pressure of regulation, as witnessed by a statement in their annual position paper.

Stricter implementation: While in the past lax implementation often prevented existing regulation from having a strong effect, the current anticorruption campaign has led to significantly increased compliance with environmental laws — not only in Western companies producing in China but also in domestic companies. In a recent case at a dye manufacturer (DyStar), several managers of the company were punished with jail terms for releasing spent sulfuric acid into a river.

Forced move to chemical parks: While currently only about half of the chemical production plants in China are located in dedicated chemical parks, this share is to increase drastically to 2020, with some provinces having set targets of 90% or more. This is partly a consequence of the Tianjin accident in 2015, which highlighted the need for a better separation of residential and industrial areas.

Growing Pressure on Chemical Companies

These are factors which indicate growing political pressure on chemical companies in China. At the same time, a number of economic factors push in a similar direction. Salaries have been rising dramatically in the past 10 years and now exceed those in many South East Asian countries. Cost pressure on producers of chemicals is increasing as there is overcapacity for many chemicals, and as the markets do no longer grow at the very high rates of the recent past, this overcapacity issue will not vanish easily. Finally, production of many chemicals is still very fragmented (for example, there are 158 producers of caustic soda), giving producers very limited pricing power and putting additional pressure on their costs.

In combination, the forces of economics and regulation will compel many chemical producers in China to upgrade their equipment, with the two main objectives of being allowed to maintain production (something that is not necessarily given any longer, as some companies such as dye manufacturer Hubei Chuyuan have experienced) and to reduce production costs to increase competitiveness. A forced move to another site at a chemical park may give an additional incentive to use this disruption of production as an opportunity.

A Need for Know-how and Equipment

And there is substantial potential for such upgrading. Even though Chinese chemical companies are already global leaders in the production of a large variety of chemicals, their production processes often lag behind world standards with regard to yield, quality, safety, waste and other aspects. Providing the know-how and equipment to upgrade these processes should therefore be an opportunity for producers of chemical production equipment and related services, both for Chinese and for foreign companies.

A number of areas seem to offer particularly exciting opportunities for equipment providers.

Control of air pollution: This topic will become more and more relevant as China will implement an environmental tax starting 2018, replacing the current emission fees and increasing the burden on heavy polluters. Companies with experience in controlling NOx emissions, e.g., by scrubbing and/or oxidation, or offering exhaust treatment by gas pervaporation should benefit from this.

Waste water treatment: Due to the previous limited interest in this topic in China, there is substantial room for improvement via introduction of modern processes such as oxidative pretreatment, ultrasonic treatment of waste, or processes that recycle waste, such as the Deacon process for recovering chlorine from HCl-containing streams in the chemical industry.

Automation: A higher automation level and introduction of a distributed control system (DCS) can lead to process cost reduction, better process control and much improved documentation. It also increases the stability of the process and consequently enhances product quality. As the Chi-

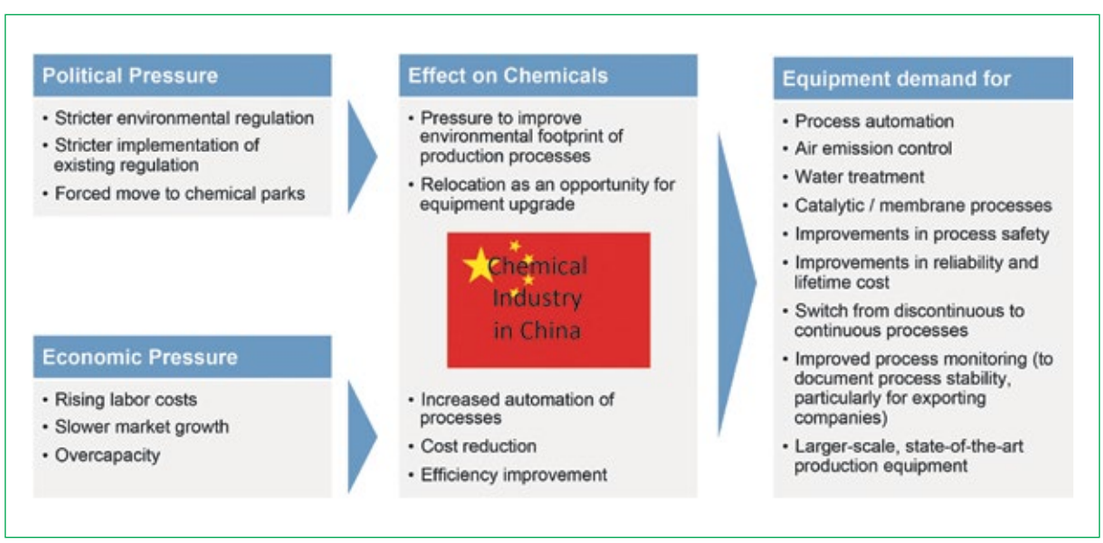

Fig. 1: Areas and drivers of demand for chemical production equipment in China.

nese government is promoting a shift towards “Industry 4.0”, the trend of automation and data exchange in manufacturing technologies, the installation of DCS can be seen as a first step in this direction.

Change of process type: Switching from a batch to a continuous or quasi continuous process (if possible) usually also leads to a better controlled and more robust process, better quality and lower investment and operation costs. As labor costs in China keep rising, such a switch may in the future be the only way for some Chinese chemical manufacturers to stay competitive. Companies that can help chemical producers to make that switch will benefit.

Introduction of membrane processes: Many Chinese production routes have been developed in the laboratory, and have never been properly optimized for large-scale use. This includes under-utilization of membrane processes. The introduction of a membrane process can lead to elimination or reduction of environmental problems, and reduce costs.

Improvements related to quality and safety: Apart from being beneficial on their own, optimizing existing processes with regard to these two parameters will be highly relevant once a Chinese company aims to supply to Western chemical companies. These companies tend to have rather high safety and quality standards, and when partnering with other players will audit their suppliers. As a consequence, quality and safety of processes need not only be established but also be documented transparently. This will bring opportunities not only for providers of quality, health, safety and environment (QHSE) equipment, but also for those providing related services such as audits.

“Production processes of Chinese chemical companies often lag behind world standards.”

Increasing importance of reliability and lifetime cost: Contrary to the general trend, in some areas of chemical equipment foreign players have actually gained market share at the expense of local players. For example, in chlor alkali electrolyzers the Chinese Bluestar has lost market share, which was gained by the Japanese and German competitors Asahi and Uhde. This is despite Bluestar offering by far the cheapest product. However, customers are increasingly aware of the reliability differences between the local and the foreign offerings and the associated difference in lifetime costs. This demonstrates that foreign players can successfully charge higher prices if there is a clear rationale. This also points to one of the challenges of targeting Chinese customers — the development of a clear value proposition that is adapted to the specifics of the Chinese market.

Growing importance of chemical parks: The Chinese government has stated the clear objective to standardize chemical parks along the lines of best practice. Currently there is strong competition among the more than 500 chemical parks in China. For providers of chemical equipment and services, it may be worthwhile to approach them directly, with the objective of helping them create an attractive infrastructure at the respective site. This could cover areas such as safety services, information services, logistics services, provision of utilities etc. In turn, chemical park owners may benefit from the established reputation of Western service providers, making it easier for them to attract new chemical companies to their park.

Conclusion

There are many factors which will force Chinese chemical companies to upgrade their production processes including cost pressure, environmental regulation and increasing quality standards. This should be a substantial opportunity for high-end providers of equipment and services for chemical companies and chemical parks. In particular, Western providers with an established track record should have an advantage over less experienced Chinese providers as the size of chemical plants increases and safety and quality levels rise.

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Digitalization in Process Industries

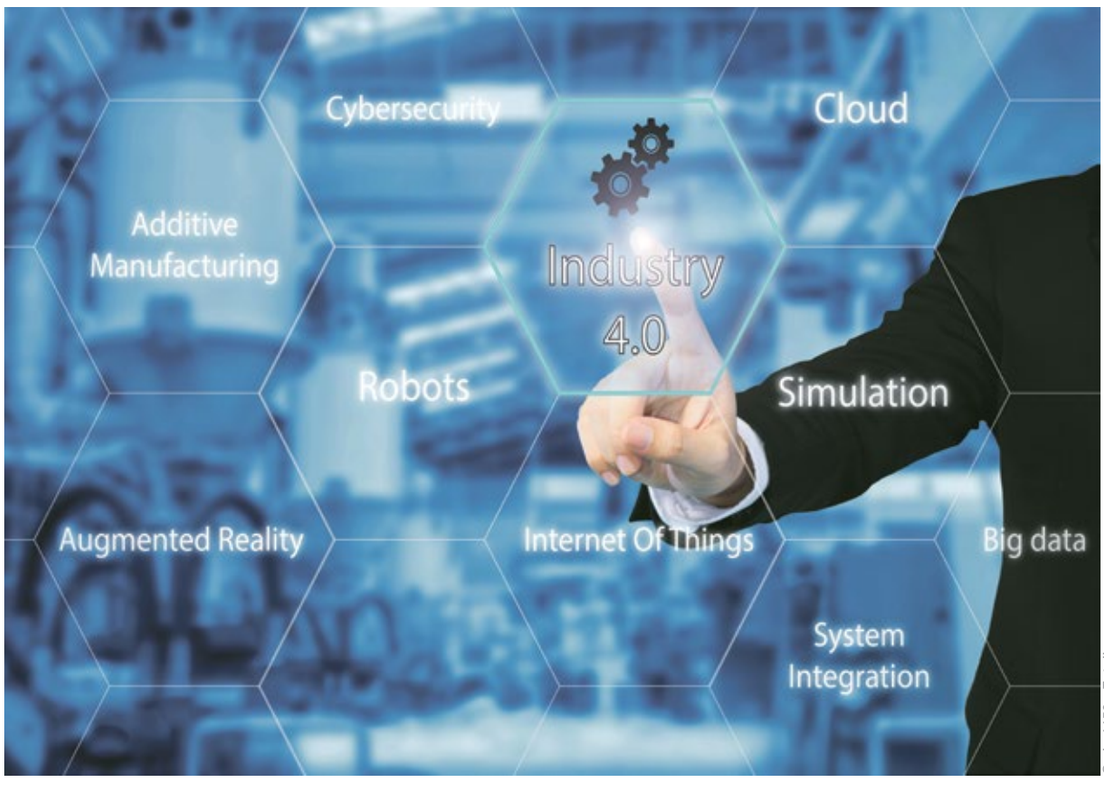
Increased Value by Cooperation of IT and OT

In a strategic alliance, Siemens and Bentley Systems plan to drive new business value by accelerating digitalization to advance infrastructure project delivery and asset performance in complementary business areas, including process industries. This cooperation aims to leverage new cloud services for a connected data environment to converge respective digital engineering models from both companies. In addition to these elements of the agreement, approximately €70 million of secondary shares in Bentley's common stock have been acquired by Siemens under a company program that will continue until such time as Bentley Systems' stock is publicly traded. CHEManager asked Greg Bentley, CEO Bentley Systems, and Eckard Eberle, CEO Siemens Process Automation, about the benefits of this cooperation to process industries. The interviewer was Dr. Volker Oestreich.

CHEManager: In November 2016 Bentley and Siemens started a strategic alliance agreement to bring more value to the customers by driving digitalization. What are the main levers in this strategy and what do Siemens and Bentley bring to this alliance?

G. Bentley: Bentley and Siemens have had a long history of collaboration and technology exchange, and you could say that we are adjacent parts of the supply chain to the owners and contractors who design, construct, and operate the world's infrastructure. Our expanded alliance will converge Siemens' capabilities in functional (2D) modeling, and Bentley's advancements in 3D physical modeling, especially for new jointly offered cloud services to extend the reach and benefits of digital engineering models. I describe our "going digital" objectives as "industrializing BIM" (Building Information Modeling), for better capital project delivery, and as "leveraging digital DNA" for better asset performance.

E. Eberle: As Greg just mentioned, we are creating a real integration between our 2D and 3D solutions and laying the foundation for the digital twin. A digital twin holds enormous benefits for designers and operators of process plants, and we help our customers to leverage the full scope of these benefits. The aim of this strategic alliance is to achieve systematic optimization of process plants throughout their entire lifecycle. This is accomplished with the interfaces between Comos as a central data management system for engineering and operation on the one hand, and Bentley Systems' 3D modeling products on the other. These enable integrated engineering and integrated operation.



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Greg Bentley, CEO, Bentley Systems

Eckard Eberle, CEO, Siemens Process Automation

With respect to process industries, where do you see the main benefit for the customers?

G. Bentley: Bentley's contribution is to bring to bear also the work of the engineers who designed, analyzed, and constructed the plant, so that their digital engineering models can serve as the connected frame of reference, and baseline, to now enable the "productioneering" of improved reliability and throughput.

For industrial plants, the continued integration of Bentley's OpenPlant with Siemens' Comos software now extends from "conceptioneering" for front-end design optimization, through raceway and cable management. The main benefits are the savings in cost and schedule, from being able to consider schematic and physical engineering decisions in the same context, across project and asset lifecycles

E. Eberle: Let me give you an example. In the early phases of a project the linkup between Comos Feed (2D) and Bentley PlantWise (3D) ensures that information needed for simulation and optimization is available earlier and in greater detail. The information within Comos Feed, for instance about flows and flow directions as well as about the equipment and its dimensions, is seamlessly available in Bentley PlantWise for automated installation engineering, pipe routing and cost estimation. The actual space requirement and the corresponding structural work can then be planned more accurately.

The plant lifecycle can be up to 40 years long, so every plant needs to be upgraded and retrofitted during this time. How can digitalization help in this field?

G. Bentley: One of the breakthrough advancements that we are applying in collaboration with Siemens is our ContextCapture software for "reality modeling", which processes digital photography to quickly yield engineering-ready as-operated 3D models for a brownfield plant. The resulting reality meshes combine images which can be "continuously surveyed" from any drone, camera, and/or smartphone, along with any available laser scans, into an immersive 3D environment. At the Hannover Messe this year we were showing how reality modeling enables Comos Walkinside to be applied within any existing plant for visual operations and training and we integrated reality modeling with other digital engineering data for a MindSphere based proof of concept, to demonstrate the convergence of OT-IT-ET.

> *"Avoidance of inconsistencies before and during the modernization process saves a lot of costs, because the project durations are shorter."*
>
> Eckard Eberle, Siemens Process Automation

E. Eberle: Modernizing and maintaining process plants is a great challenge. Such projects are often difficult to plan and calculate — one reason being that it is not uncommon for considerable differences to arise between the originally planned and the actual state of the plant. Changes implemented over the years are not entered at all or not entered in full in the plant documentation. Thanks to the object-oriented data model and the open system architecture in Comos, data and documents from the engineering and operating phases can be easily imported into the plant lifecycle management system at any time. Data from a wide range of sources, for instance from

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Bentley Systems, is maintained centrally, enabling enhanced maintenance engineering so that plants can be put back into service more quickly.

> *"By starting with reality modeling, there will be increasingly robust digital twin representations for industrial assets."*
>
> Greg Bentley, Bentley Systems

Successful plant operation is due to transparent modernization and maintenance. The resulting digital twin provides a solid basis for efficiency-boosting measures and facilitates the retrofitting or extension of existing plant sections, thus simplifying and accelerating modernization projects. When the plant is running again, XHQ visualizes and monitors key operational and business indicators practically in real time to secure the competitive edge accomplished with the modernization.

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Cambrex Expands Charles City API Plant

Cambrex Corporation, a US manufacturer of active pharmaceutical ingredients (APIs) has announced another expansion to boost its global network. This latest project will see an investment of $24 million in a new facility to manufacture highly potent APIs (HPAPIs) at Charles City, Iowa, USA.

The 4,500 ft² production area will operate to an occupational exposure limit (OEL) down to 0.1 µg/m³ and have a total reactor capacity of 2,200 gallons, which will consist of a range of 200, 500 and 1,000 gallon glass and Hastelloy vessels to manufacture batches from 50 kg to 300 kg.

The project will also reconfigure the existing small-scale manufacturing area and provide a single, high containment building to support early stage development and manufacturing, Cambrex said. (eb, rk)

KBR Wins Russian Ammonia Contract

Engineering and construction group KBR has been awarded a contract by Dorogobuzh JSC, a subsidiary of Russian fertilizer producer Acron, to provide licensing and basic engineering design services for an ammonia plant revamp. The value of the contract was not disclosed.

KBR will supply its proprietary ammonia technology, which will increase capacity at the plant in Dorogobuzh in Russia's Smolensk region to 693,000 t/y.

The contractor said it will use its KBR Reforming Exchanger System (KRES) together with its True Cold Wall Add-on Converter to achieve a revamp at low cost that will enable Dorogobuzh to produce low-cost ammonia to meet increasing captive demand. A timescale for the project was not provided. (eb, rk)

Perstorp Upgrades UK Peracetic Acid Plant

Swedish specialty chemicals company Perstorp is upgrading its peracetic plant in Warrington, UK. The upgrade will see a new still and reactors installed, replacing existing equipment that was built in 1998. The project is expected to be completed in the second half of 2019.

Peracetic acid is used in the manufacture of caprolactone, from which Perstorp makes its Capa high molecular weight linear polyester. "The Capa business is one of our strategic areas and we do see a strong market demand," said Marie Grönborg, executive vice president. The company said the significant investment would "future-proof production and even further increase security of supply."

The company doubled caprolactone production at Warrington in 2011 in order to meet fast-growing demand. (eb, rk)

Sadara Starts Final Unit at Jubail Complex

Sadara, the joint venture between Dow Chemical and Saudi Aramco, has started up the last of the 26 plants that make up its massive new petrochemical complex at Jubail Industrial City II in Saudi Arabia.

The newest plant produces crude quantities of toluene di-isocyanate (TDI) and other specialty chemicals and is one of three integrated units, the other two producing dinitrotoluene (DNT) and toluene diamine (TDA). The DNT and TDA units started operations in April. A facility to produce polymeric methylene diphenyl di-isocyanate (PMDI), integrated within the isocyanates section, began producing commercial quantities in June, and a plant producing 400,000 t/y of polyurethane precursor polyether polyols went on stream in late July. Sadara has been bringing the plants on stream sequentially over the past few years. (eb, rk)

Putting the ROI into IIoT

Top Operational Performance in the Process Industries

Oil and gas, petrochemical, refining, life sciences and other manufacturing companies face ongoing pressures to achieve improved financial results. Enhancing the economic performance of existing assets can help them accomplish that goal. However, despite years of operations improvement programs, the results have been disappointing for many thus far. Dr. Volker Oestreich asked Roel Van Doren, President Europe, Emerson Automation Solutions, about Operational Certainty, Top Quartile Performance and the IIoT (Industrial Internet of Things).

CHEManager: Over the past year, Emerson has analyzed the operational performance of industrial companies in order to identify behaviors and actions that separate Top Quartile performers — defined as achieving operations and capital performance in the top 25% of peer companies — from those in the lower tiers. What are the outcomes?

R. Van Doren: Through close cooperation with benchmarking companies and talking to our customers, we have gathered industry-wide data on the challenges companies face in core areas like safety, reliability, production and energy/emissions. Our findings show that across the global industrial sector, annually as much as $1 trillion is lost as a result of subpar performance.

This is an enormous potential for improvement. How did you react?

R. Van Doren: We have introduced Operational Certainty, a technology and engineering-based program, designed to help manufacturers reach Top Quartile performance in the four key areas mentioned above. A fundamental strand of Operational Certainty includes delivering on the promise of IIoT, the Industrial Internet of Things, and enabling companies to implement IIoT applications that can help them achieve a significant return on their investment.

What is your roadmap to help industrial companies to achieve Top Quartile performance and recover some of the operational losses you have figured?

R. Van Doren: Because of limited peer benchmarking and uncertainty over which approaches will yield the greatest improvements, many companies in the industrial sector have become stuck in decades-old work practices that fail to take advantage of available advanced digital technologies — their performance levels are suboptimal.

The key to companies setting and achieving improved performance goals is first to understand what is possible based on today's available technologies and which levers can deliver measurable results. Working closely with leading benchmarking companies and our customers, we have identified the most important behaviors and actions that separate Top Quartile performers from those in the lower tiers.

Can you name some typical cases?

R. Van Doren: Top Quartile performers had one-third the number of safety incidents compared to their average industry peers. They spent half as much on maintenance compared to average performers and had an increased production availability of 15 days per year. Top Quartile manufacturers spent 20% less on production-related expenses compared to average producers, and, last but not least, they spent one-third of the industry average on energy costs and had 30% less CO_2 emissions.

How can companies in the process industries become Top Quartile performers?

R. Van Doren: With a desire to help our customers to achieve Top Quartile performance, we have launched Operational Certainty, a technology and engineering-based program designed to help recover that $1 trillion in operational losses.

A critical part of Operational Certainty is the use of new peer benchmarking insights to bring a better perspective on best practices and technologies to achieve Top Quartile performance in the areas of safety, reliability, production and energy management.

The path to Top Quartile performance starts with an Operational Certainty workshop. These sessions help to pinpoint the root causes of poor performance, prioritize actions that can yield the greatest improvement and establish a scalable work plan for achieving those results.

With customers hungry for new ideas and looking for proven ways to harness the power of IIoT to make technology work in measurable, meaningful ways, Operational Certainty can have a transformational impact on their performance.

What backing do you give your customers when introducing Operational Certainty?

R. Van Doren: We have also launched a new Operational Certainty consulting practice, plus expanded project execution methodologies and resources. Additionally, Emerson has announced its new Plantweb digital ecosystem to provide the technology foundation for companies to securely implement the IIoT to achieve measurable business performance improvements.

We know precisely what behaviors are delivering industry-leading performance and what is required for other companies to reach those levels. With our industry expertise, consulting services, comprehensive automation technologies portfolio and new IIoT solutions, we can help customers leverage the best practices and strategies of Top Quartile performers, and improve their earnings by as much as 15%.

What role does the IIoT play in Operational Certainty?

Roel Van Doren, President Europe, Emerson

R. Van Doren: Perhaps the biggest industry technology buzz we hear today is about IIoT. Distributing data and information seamlessly via the internet makes IIoT the new frontier of manufacturing — it has even been referred to as a phenomenon that will reinvent manufacturing. Clearly IIoT is an important part of the fourth industrial revolution we find ourselves in. IIoT is pivotal to Operational Certainty because we can leverage the benefits of IIoT to help companies improve their operational performance.

IIoT applications most usually go together with applications in the cloud. What is your strategy for cloud services?

R. Van Doren: We have standardized on the cloud-based Microsoft Azure IoT Suite to enable Connected Services, expanding Plantweb to provide a secure, flexible platform for private cloud networks and third-party cloud service relationships. The Azure IoT Suite is a scalable and secure cloud application environment which offers a broad range of capabilities that help industrial manufacturers to confidently adopt IIoT. The Azure IoT hub already processes billions of messages every week, resulting in the generation of intelligent insights, enabling companies to implement the actions that will lead to significant business performance improvement.

Our partnership with Microsoft creates IIoT services that can improve customers' overall operational performance and efficiency. Extending a more than two-decade relationship between the companies, we are also broadly adopting Microsoft's Windows 10 IoT technology, both in our DeltaV and Ovation control sys-

tems and in data gateways, for local data processing and to serve data to the Azure IoT Suite.

To power its IIoT applications, Emerson chose Microsoft for its comprehensive offerings that span both the intelligent edge, with Windows, and the intelligent cloud, with Azure. These capabilities should ultimately remove the need for in-house domain experts, as we will provide the real-time monitoring of infrastructure that manufacturers require. Both the Azure IoT Suite and Windows 10 IoT have a proven record of success in industrial applications. By integrating these Microsoft offerings, we can expand Plantweb to cloud applications that can also be delivered in a turnkey 'connected service' model for the entire enterprise.

The combination of our application expertise hosted on Microsoft Azure will provide a compelling suite of IIoT applications to expand digital intelligence to the entire manufacturing enterprise. These applications will be easily and quickly deployable and have immediate quantifiable business benefits for industrial manufacturers looking for better operational performance.

How will investing in IIoT applications improve operational performance?

R. Van Doren: IoT makes it possible to either empower your company's experts with the additional information they need for decisions and action that can facilitate operational performance improvements, or for the first time to completely outsource that analysis and decision making to third party domain experts. There are four critical aspects to achieving this: the provision of rich, real-time operating data from intelligent sensing and automation technologies across the business; secure transport of that data to where it's needed anywhere in the world; robust, scalable software to convert the data into actionable insights; and domain expertise to make the decisions and drive the outcomes that will lead to improved performance. A new business model called Connected Services has also emerged where those last two pieces are performed by a remote third party rather than in-house experts.

> *"We have identified the most important behaviours that separate Top Quartile performers from those in the lower tiers."*

Is IIoT's potential now being delivered?

R. Van Doren: I believe so. There has been so much talk about the promise of IIoT and this will probably be a major topic of discussion at the Emerson Exchange in The Hague next year. But the company is now delivering on that promise with a compelling and clear business case in Operational Certainty and with the most robust, scalable technology and service platform with the Plantweb digital ecosystem. We are now putting the ROI into IIoT.

www.emerson.com

Right Time, Right Message

Specialty Chemicals Manufacturer to Optimize its Production

Evonik Industries is one of the world's leading specialty chemical companies. In one of its production plants in Singapore it produces oil additives and technologies for fuels and lubricants for the fast-growing Asia-Pacific market. As part of its digitalization strategy and to optimize its production output, the company relies on automation with an efficient process alarm management.

"Companies in the chemical industry are facing an increasing competitive pressure. Our aim is at any time to ensure safety, availability and connectivity of our production plants leading to operational efficiency. At Evonik we focus on new technologies as well as on new business. For us digitalization is one of the key levers to tackle all these challenges. With Siemens we have a reliable partner at our side to realize our digitalization strategy into our production plants globally," says Peter Meinshausen, regional president, Evonik Asia Pacific South.

At its production site in Jurong Island, Singapore, the firm installed a distributed control system Simatic PCS7 together with a tailored alarm management system from Siemens. It helps to support control room operators by prioritizing the alarms and send them to the responsible personnel or departments. This has reduced the incidence of alarms received in the control room by more than half.

Creating Meaningful Information

Process automation and other control and monitoring systems allow production plants to collect more detailed data during production processes. The challenge is to collate data and create meaningful information that will help operators in making timely as well as informed decisions. This challenge is especially important for alarm systems in production plants: if the frequency of alarm notification exceeds a certain level, this increases the likelihood of operator making mistakes, and might also potentially impact the process performance and safety of the production plant. These risks can be mitigated by an alarm management system that filters and prioritizes alarms.

One company that recently implemented a solution for alarm management is the specialty chemicals manufacturer Evonik. To serve the rapidly growing Asia-Pacific market, it opened its oil additives plant in Singapore in 2008, and has significantly expanded the plant in 2015, making it the largest oil additives production site within the company's global network. The process control system used at the Singapore site is based on Simatic PCS 7 and Simatic Batch. The entire plant

© Evonik

Evonik Oil Additives plant in Singapore

Adnan Bin Abdul Rahman, Siemens

is operated by a central control room with two operating stations — one for monomer production and another for polymer production. Products are produced by order in batches to allow frequent process adaptations.

Reducing Workload, Improving Performance

When the plant was expanded some time ago, Evonik also looked into improving its existing alarm management system, by discussing the requirements and strategies with Siemens. To ensure the solution meets the international standard, engineering and consulting experts from Siemens followed a structured approach comprising the development of a suitable alarm concept, data collection and system benchmarking, "Bad Actor" alarm resolution, alarm documentation and rationalization, real-time alarm management, and lastly, implementation in the DCS. Working closely with personnel from the plant, the Siemens team tailored the alarm management system by integrating the existing user requirements and best practices from the Evonik site in Darmstadt, Germany. Implementation of the new alarm management into the chosen system and corresponding application software was performed by the local Singapore Siemens team.

One crucial success factor of this project was the involvement of the plant operators in the concept and design phase, which allowed their years of operational experience to be applied in the design and creation of the solution. The Singapore Siemens team organized several workshops throughout the project to support the alarm evaluation and prioritization process, and to identify the causes of "Bad Actor" alarms. One key feature of the alarm management

system is the Advanced Alarm Suppression concept, which filters and aggregates alarms. Tailored alarm prioritization according to urgency and consequence ensures that operators are always presented with the most important alarms. As part of the new concept, the alarm cockpit in the plant was also redesigned. Alarms are now aggregated into several logging lists, with one for all incoming process alarms and another for PLC process control messages. This concept ensures that process-related alarms are directed straight to the operator, while other alerts are sent to the plant maintenance personnel. As a result, tasks can be dealt with in a timely manner as they are quickly assigned to the right person.

Positive Feedback from Operation

The new alarm management solution has exceeded Evonik's expectations. In terms of the alarm optimization system, it was able to effectively address the issue of operator stress in its Singapore plant. Following smooth implementation without any system downtime, the number of process alarms displayed in the control room has been reduced by more than half. In addition to the alarm management solution, Siemens also supported its client in implementing several system improvements. The plant personnel have easily adapted to the new solution and are already experiencing the benefits in their daily work.

"Proper alarm management impacts process performance and safety — thus reaching operational excellence."

Peter Meinshausen, Regional President, Evonik Asia Pacific South

World-scale Amino Acid DL-methionine Plant

To better serve the strong demand and customers in Asia, in 2016 Evonik started the construction of its second world-scale methionine complex in Singapore. With additional annual capacity of 150,000 metric tons, the new production complex will increase the producer's annual capacity of DL-methionine to a total of approximately 300,000 metric tons in Asia, and to approximately 730,000 metric tons worldwide. The plant is expected to start operations in 2019 and Siemens also was commissioned as one of the partners for the energy management solution for the new plant. "We always strive to exceed the expectations of our customers with innovative and competitive solutions," commented Peter Meinshausen. "We have been partnering with Siemens to enhance our plants' alarm and energy management, and I believe we can achieve greater operational efficiency for our production plants together."

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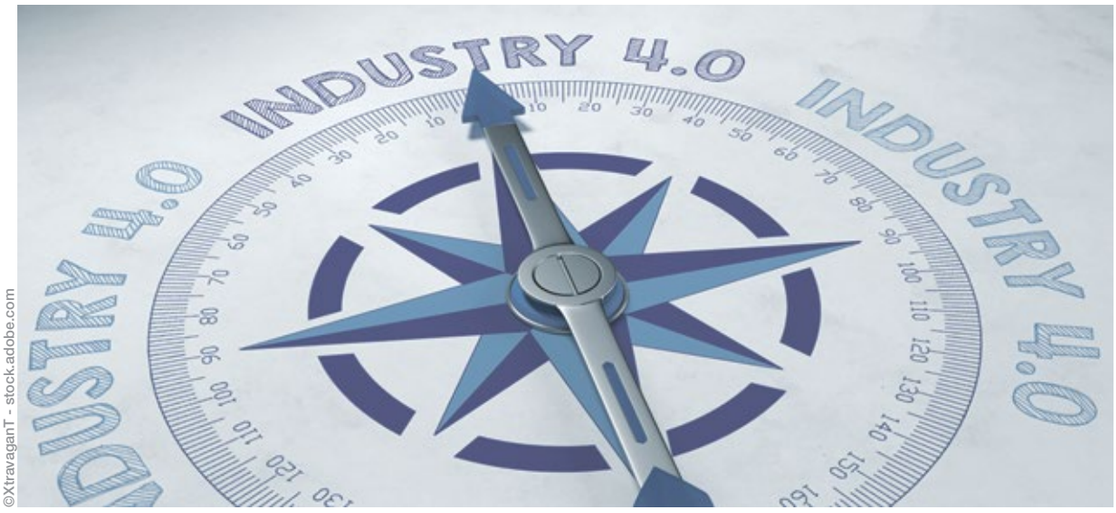
Facilities of the Future

Major Trends and Drivers for Innovation in Pharmaceutical Manufacturing

More than ever the factory of the future must consider the requirements of a permanently changing product portfolio. Mergers and acquisitions lead more frequently to product transfers and closing down of older factories. Variations on market demands and shorter product life cycles can turn big production volumes to smaller ones and the other way around. The block buster model is decreasing and the diversity of the product portfolio will be increasing. The impact on manufacturing facilities will be a higher complexity on all levels of activities.

Dr. Thomas Zimmer, ISPE



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Flexibility and Agility

As a consequence, new factories must be able to be flexible and to react in time on changing demands, changes in product portfolio and new regulatory requirements. Product change-over-times on machines and equipment must be drastically reduced without negative impact for patient health and safety or on regulatory compliance. Single use technologies will be used as one lever. Investments need to be planned diligently and as late as possible in order to meet changing market demands in time. This requires excellence in project management. The factory of the future might be modular in order to be able to reconstruct one part while continuing the production in the other part.

Technology Platforms and Integration

Industry 4.0 will provide a lot of innovative impulses: End to end integration of computerized systems along the value chain, digitization and automation. As a premise data integrity must be ensured and respected in all functions of a pharmaceutical company, including finance/controlling and human resources. Integrated systems allow disclosing additional saving potentials not achievable so far in a world of „silos".

"In principle, regulatory agencies welcome innovation when quality and safety is not compromised or even stabilized."

Readiness for Innovation in Manufacturing

Some products of the legacy product portfolio will not be ready for a transfer to the new Industry 4.0 or Pharma 4.0 world as the product design and the related production processes are not suitable to be transferred into an automated process. They were developed in order to meet other target profiles and need to be re-developed or upgraded in a more or less time and cost consuming change management process.

How Authorities Evaluate Innovation

One of the most innovative approaches to regulators seems to be continuous manufacturing, in particular in biotechnological production and in the production of small molecules and active pharmaceutical ingredients. Processes can be shortened, the availability of drugs in the market can be increased, what is of essential interest for the health agencies.

Another sector is using new technologies for „personalized medicine" which drives technologies suitable to make small and smallest batches. Early in the maturity process are trials with 3D printing of unit doses. „Galencial science" is still to be developed, e.g. sustained release from such dosage forms.

More advanced are „single-use" technologies which eliminate expensive cleaning validation, often reason for findings in GMP inspections when not performed correctly.

In principle, regulatory agencies welcome innovation when quality and safety is not compromised or even stabilized. Very often, new approaches lead to many questions from regulatory reviewers perceived by the applicant like „acts as a brake". Therefore the innovator must spend energy in communication and explain also for technical non-experts the plausibility and the quality risk management concept of the innovation.

„The factory of the future must consider the requirements of a permanently changing product portfolio."

Continuous Manufacturing: A Future Common Practice?

Where continuous manufacturing will disclose advantages a trend has been established. Big volume and high value products can absorb the cost for investment in continuous manufacturing. For small products suitable processes via miniaturization of equipment must be developed.

The general advantages lies in avoidance of any problem linked with scale-up development, e.g. changed physical parameters in big reactors or high volume tablet machines compared with those from the equipment used in development.

Challenges of Implementing Mass Serialization Processes

The implementation of 2D matrix codes on packaging is not a new technology. The challenge for the phar-

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maceutical industry is more linked with the complete integration of all computerized systems along the value chain between starting materials and finished goods dispensing place (e.g. pharmacy), as this is the distance for verification of potentially falsified medicines. The integration of computerized systems is based on technical standards as defined in GAMP (Good Automation Practice) guidelines from ISPE, not only standardized product codes. Such technical communication standards must also consider the ownership of different parts of the product code, e.g. Global Trade Identification Numbers (GTIN) have other owners than national codes in the same product identification system. Some industry consortia work on these questions, e.g. OPEN SCS.

Advanced Aseptic Processing

The Pharmaceutical Industry is currently waiting for the first regulator's draft on the complete revision of Annex 1 EC GMP Guide expected for late 2017. Therefore the discussions focused on progress on known areas of technology, e.g. when is the use of isolators indicated and where the use of RABS (Rapid Access Barrier Systems). How far can manual interventions be circumvented in aseptic filling processes? Which options for the use of robots do exist? Where is the advantage of single-use technologies? How can multi-purpose factories be safely run on the basis of RABS?

"Companies have realized that data integrity is a hot issue for the entire value chain, as almost everywhere compliance-relevant data are handled."

Data Integrity Is Key

New regulations from the Medicines and Healthcare products Regulatory Agency (MHRA), the World Health Organization (WHO) and the Food and Drug Administration (FDA) drive intensive discussions at industry. Companies have realized that data integrity is a hot issue for the entire value chain, as almost everywhere compliance-relevant data are handled. Correctness, completeness and distinctiveness of data are also parameter of GMP, therefore data integrity can be considered like „GMP for data". Triggered by this, many companies have started standardization of data warehouses and also started frameworks for Master Data management as these are enablers for successful implementation of data integrity requirements.

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Jacobs to Acquire CH2M for $3.3 billion

US contractor Jacobs Engineering has entered into a definitive agreement to buy CH2M in a cash and stock transaction with an enterprise value of about $3.27 billion, including roughly $416 million of debt.

Based in Denver, Colorado, USA, CH2M is a design, engineering and program management firm with 20,000 employees and revenues of about $4.4 billion in the past 12 months.

The acquisition enhances Jacobs' position in the petroleum and chemicals industry by providing additional operational and maintenance capabilities for both upstream and midstream clients and enabling infrastructure for major petroleum and chemicals projects.

Jacobs expects to achieve $150 million of annual run-rate cost savings by the end of the second year after the transaction closes, incurring one-time costs of about $225 million as a result.

Savings are expected to come from real estate, optimization of corporate operations, alignment of organizational structures, procurement and IT systems.

To fund the $2.4 billion cash required, Jacobs will use a combination of cash on hand, borrowings under an existing revolving credit facility and $1.2 billion of new committed three-year term debt. (eb, rk)

CB&I to Sell Technology Business

US engineering contractor CB&I is putting its technology business up for sale as it struggles with falling revenues. The Texas-headquartered group reported a second-quarter loss of $425 million and revenues down more than 40% year over year.

"Although our second-quarter results are disappointing, we are taking decisive actions to improve our operating performance and strengthen the company's financial position," said president and CEO, Patrick Mullen.

"We have initiated a comprehensive cost reduction program and suspended our dividend. Additionally, we are pursuing a sale of our technology business, which we believe will unlock significant value for stakeholders."

Mullen said proceeds from the sale will be used to wipe out most of CB&I's debt and reinvest in its engineering & construction and fabrication services businesses.

"We envision a bright future for CB&I as a highly focused company with tightly integrated EPC [engineering, procurement and construction] and fabrication capabilities serving the LNG, petrochemical, refining and gas power generation markets."

The technology business includes about 3,000 patents and patent application trademarks and more than 100 licensed technologies. CB&I is aiming to close the deal by the end of 2017. (eb, rk)

Flow Chemistry Down Under

Microreaction Technology for Modular Manufacturing of Fine Chemicals and Pharmaceuticals

The Commonwealth Scientific and Industrial Research Organization (CSIRO), with its long and storied history in chemical innovations, has developed significant capability in flow chemistry as a key driver of process intensification and has recently launched "FloWorks", a centre for industrial flow chemistry in Clayton, Victoria — a purpose-built 410 m² pilot scale facility.

The collaborative technology platform will be a foundry available for industry and research bodies to partner and develop flow chemistry processes. It offers a range of engagement models from early discovery stages to pilot scale and technology transfer (fig. 1).

Polymers

Flow reactors from laboratory scale (a few grams) to pilot plant scale are available and given CSIRO's capabilities in polymer chemistry and science, a range of polymerization methods and flow chemistry technologies are offered.

Reversible Addition-Fragmentation chain Transfer (RAFT) polymerization technology is an established form of controlled free radical polymerization which allows the rational design of well-defined polymeric structures. It can be used in a wide range of monomers and reaction conditions and provides access to polymers with unprecedented control over size, composition and architecture. RAFT can be used for solution, emulsion and suspension polymerizations, in batch, as well as flow chemistry.

Anionic polymerization is another form of controlled addition polymerization of vinyl monomers, providing access to polymers with predicted molecular weights, narrow molecular weight distributions, and defined end-groups. The ability to perform anionic polymerization using continuous processing methods (flowchemistry) removes the problem of batch-to-batch reproducibility encountered using batch processing.

Condensation polymerization is a step-growth polymerization process that can be used with non-vinylic monomers. CSIRO has used this technology to design and synthesize biostable and biodegradable polymers.

Catalysis

CSIRO combines expertise in early stage discovery and development of catalytic processes, incorporating new manufacturing technologies such as 3D metal printing and metal cold spraying. Early stage discovery can include catalyst high throughput screening at CSIRO's automated high-throughput facility and chemical process development of the synthetic route at bench scale.

The transfer to commercialization involves process scale-up to pilot or pre-commercial scale using intensified continuous flow processes, techno-economic analysis and the final technology transfer to the commercial partner for chemical production.

CSIRO's research in continuous flow solutions for chemical catalysis includes a series of cutting-edge capabilities, which are described below.

Catalytic Static Mixers (CSMs): The current methods for heterogeneous catalysis using packed bed reactors pose many limitations. Fluid flow through the bed, as well as temperature and concentration gradients, can often be highly non-uniform, making heat control difficult — especially on large scale. For liquid phase applications, pressure drop along the bed can also be highly problematic. The size and shape of catalyst particles determine the performance of the catalytic reaction and the physical processes occurring inside the reactor — such as fluid flow, mixing as well as heat and mass transfer — often lead to undesirable limitations.

A different approach is needed. Working with additive manufacturing experts, researchers at FloWorks are developing a hierarchical catalytic reactor approach. This new method involves a tailored, 3D printed mixing solution married with a range of active catalyst coatings for different catalytic reactions. The tubular design of the continuous flow reactor provides superior process control when compared with packed bed columns or stirred batch vessels.

The metal mixer scaffolds can be designed and manufactured to the fluidic application, before the catalyst is directly deposited via electroplating, cold spraying, or other deposition methods. The Catalytic Static Mixers (CSMs) can be readily inserted into reactor tubes, allowing for easy changeover of catalyst. This makes the CSM technology a versatile and efficient tool for R&D and chemical production.

As hydrogenation is one of the most common reactions used in the chemical manufacturing industry, the CSM reactor concept has been developed for a series of metal-catalysed gas-liquid hydrogenations and transfer hydrogenations in continuous flow. High turn-over-frequencies and space-time-yields were achieved with very low leaching of the metal catalyst. The technology can be adapted to a number of different manufacturing sectors including: pharmaceuticals, fine chemicals, food products/supplements, polymers and agrochemicals.

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Fig. 1: FloWorks — a dedicated facility for the development of industrial scale flow chemistry processes.

Fig. 2: A pilot scale tubular continuous flow reactor for manufacture of metal organic frameworks (MOFs) developed at CSIRO.

Homogeneous Catalysis using Tube-in-Tube Flow Reactors: Researchers at CSIRO in collaboration with the University of Cambridge and the University of Melbourne have developed a new tube-in-tube flow chemistry reactor system for a range of gas-liquid phase catalytic applications. The tubular membrane system allows both heterogeneous and homogeneous catalytic reactions to be carried out at elevated pressures in a continuous flow mode, leading to improved inherent safety of these processes.

The use of a gas-permeable fluoropolymer, Teflon AF-2400, is a simple method of achieving efficient gas–liquid contact to afford homogeneous solutions of reactive gases in flow.

The membrane permits the transport of a wide range of gases, including H_2, O_2, O_3, CO, NH_3 and others, allowing for key C–C, C–O, and C–N bond forming and hydrogenation reactions.

Advanced Porous Materials

Hyper-porous materials — including metal-organic frameworks (MOFs) and their metal-free counterparts, covalent organic frameworks (COFs) — have attracted much attention in recent years owing to their vast potential for application to areas such as energy and gas storage, separation science and catalysis. The availability of scalable synthesis methods is a significant challenge for the translation of MOFs and COFs into industry. Over the last decade, CSIRO has met this challenge through the development of scalable continuous flow methods for the synthesis and manufacture of these materials.

For example a continuous flow MOF production process that is scalable to multi-kilogram per day production has been developed (fig. 2). The process is efficient delivering a range of MOFs with surface areas that consistently match those reported from laboratory scale synthesis and high space time yields. The use of propriety downstream processing ultimately produces MOFs in a variety of palletised formats and geometries.

Covalent organic frameworks (COFs) are three-dimensional organic porous and crystalline polymers with extended structures in which building blocks are linked by strong covalent bonds. COFs are comprised entirely from light elements (H, B, C, N, and O) and can therefore be considered the organic analogues of MOFs. A unique feature of COFs is that the physical properties of the framework can be tailored via judicious choice of the geometry, dimensions and functionality of the organic building blocks. COFs are known to exhibit unique photo-physical properties that can be employed as platforms for catalysis and have recently emerged as attractive materials for application in gas adsorption and separation science.

CSIRO also has developed scalable continuous flow methods for the synthesis of carbon-based molecular cages. Covalent organic cages are a subset of COFs that are discrete molecules rather than extended solids. These novel porous materials can be solution processed which is a significant advantage over their solid-state counterparts.

The manufacturing platform will pave the way for the industrial uptake of this new class of carbon-based hyper-porous materials.

CSIRO

The Commonwealth Scientific and Industrial Research Organization (CSIRO) is a Statutory Authority of the Australian Government and was founded in 1916, mandate to assist the Australian industry and fulfil the national and international obligations of the Commonwealth. The Australian chemical industry is a critical enabling industry in Australia, feeding into almost every other industry sector. In recent years, the chemical community in Australia has come together and put forward two important roadmaps. In the first, the Australian Academy of Science has detailed a Decadal Plan for Chemistry, while at the other end of the spectrum Chemistry Australia has put forward a road map for the chemical industry. Collectively these documents identify continual innovation and sustainability as key drivers for the industry going forward.

Summary

Through the right people, networks, equipment and facilities FloWorks has developed sustainable and financially viable flow chemistry technologies for its partners and has deployed new processes into the Australian chemical industry.

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SAP Mobile Applications for Asset Management, 25. – 26. October 2017, Amsterdam, The Netherlands

Asset intensive organizations operate within challenging and volatile markets. They are under ever increasing pressure to increase efficiency, reliability and availability, while maintaining and improving bottom line.

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Achema 2018, 18. – 22. June 2018, Frankfurt, Germany

Achema is the world forum for chemical engineering, process engineering and biotechnology. Every three years the world's major fair for the process industry attracts around 4,000 exhibitors from over 50 different countries to present new products, processes and services to 170,000 professionals from all over the world.

The spectrum ranges from laboratory equipment, pumps and analytical devices to packaging machinery, boilers and stirrers through to safety technology, materials and software, thus covering the entire needs of the chemical, pharmaceutical and food production industries. The accompanying congress, featuring 800 scientific lectures and numerous guest and partner events, complements the wide range of themes of the exhibition.

www.achema.com

ISPE Biopharmaceutical Manufacturing Conference, 4. – 6. December 2017, San Francisco, California

The International Society for Pharmaceutical Engineering (ISPE)'s conference will expand the conversation beyond manufacturing capacity needs to address innovative operational and process development strategies to speed preparations toward launch readiness.

The event features three education tracks with comprehensive sessions offering solutions from industry, regulatory, and academic experts. Attendees will gain insight into innovative strategies and approaches designed to improve operational agility and preparation time for launch readiness. Regulatory perspectives on how to implement new manufacturing capabilities and advancements to insure timely licensure will be presented.

www.ispe.org

Index

Imprint

Publisher
Wiley-VCH Verlag GmbH & Co. KGaA
A Company of John Wiley & Sons, Inc
Boschstr. 12, 69469 Weinheim, Germany
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Original Articles:
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Printed by: DSW GmbH, Ludwigshafen, Printed in Germany

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Special Focus Issues

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