**How global megatrends are changing mechanical process engineering - and making it cool**

*What do the trend topics of circular economy, battery production and plant proteins have in common? They challenge the creativity of process engineers, and they follow the global megatrends of resource scarcity, mobility, nutrition and climate protection. Where the focus in the past decade was on new chemical processes and digital technologies, now it is the turn of mechanical process engineering.*

The future belongs to the electrification of the economy and mobility. And storage technologies will play a decisive role in this. But if you ask experts where the greatest innovation potential can be expected in battery technology, the answer will surprise most people: Not in chemistry and new materials, but in production technology. While, for example, a technological optimum is visibly in sight for lithium-ion batteries on the materials side, the production of battery cells and batteries is still far from mature. For example, the energy density, service life and performance of battery cells in general and especially at low temperatures depend crucially on the precision of particle sizes and shaping. And although China is currently the undisputed market leader in the production of batteries for electric cars, this could change in the coming years if new players in the USA and Europe build new battery factories with the latest technology in large numbers.

Researchers from the Fraunhofer Institute for Manufacturing Engineering and Automation, IPA, are convinced that the key to this lies in the production process. Mechanical processes are an important factor: They enable the production and processing of nanomaterials and the precise manufacture of electrodes. The complexity of the battery value chain already begins with the extraction of raw materials through mining or chemical extraction - but the process gets really tricky when it comes to processing the materials: these not only have to be produced in consistently high quality ("battery grade"), but also in large quantities. And because active battery materials are toxic, the production processes must also be hermetically sealed (containment).

Manufacturers of mixers, dispersers and reactors have taken up the issue. One example is the further development of tubular reactors for powder synthesis: in the tubular reactor from Glatt Ingenieurtechnik, for example, a pulsating hot gas flow ensures turbulent flow conditions and makes it possible to adjust the size, surface and structure of particles precisely and reproducibly. But it is not only in reaction technology that temperature distribution has a major influence on product quality. Because anode and cathode materials are often produced in high-temperature processes, heating, flow control and insulation of the production machines are also important.

Another process step in battery production is the coating of the carrier foils to which the active material is applied. The coating mass must be particularly homogeneous here, because deviations in particle size or viscosity lead to performance losses. New mixing and dispersing machines such as those from Ystral aim to precisely control the energy input and minimise the energy requirement - an important optimisation goal in view of the large quantities to be processed.

**Continuous processes require new machine technology**

Continuous processes are becoming increasingly interesting: In contrast to classic batch production, productivity increases with continuous processes because downtimes and cleaning times are eliminated. In addition, continuous processes enable better control over the production process, can be designed to be hermetically sealed more easily and achieve higher product qualities. This is particularly important when the product is sensitive to contamination or germ contamination must be avoided. Furthermore, continuous processes are easier to scale up and lead to higher energy and cost efficiency.

But to achieve continuous processes, mechanical processes have to be adapted or newly developed: Whether mill, mixer, dryer or centrifuge - the design of machines for continuous processes follows other laws. The rethinking with the objective of "continuous" is already leading to new designs. One example is the nozzle separators recently developed by Flottweg, which are used for the continuous separation of solids from liquids, for example in biotechnology. In contrast to classic centrifuges, the machine uses a comparatively light drum and thus requires significantly less drive energy.

Another example are continuously operating extruders used in the recycling of plastics. For example, twin-screw extruders from Coperion ensure highly efficient energy input into the plastic melt during thermal recycling of the plastic polymethyl methacrylate (PMMA), resulting in fast and energy-efficient depolymerisation.

**Circular economy: potentials for chemical and mechanical recycling**

The machine development sheds light on the growing future market of the circular economy: the production of plastics on the basis of chemical recycling is a forward-looking option in it. However, breaking down polymers into their chemical components is only the last step. In view of the energy balance, mechanical recycling is much more sensible, but so far it has often failed because plastic waste is usually not sorted by type. Digital technologies should help here in the future. Artificial intelligence and machine learning can evaluate the data from cameras and sensors on the sorting machines and separate the plastic waste into different fractions - also with the help of robots.

Increasing recycling rates are also a challenge for the mechanical processes: Plants are reaching their capacity limits. Because mechanical mixers, for example, are limited in their sizes and the mechanical forces also increase with the quantities, quality fluctuations occur in PET recycling when mixing PET flakes. Mixing silos, in which the bulk material is extracted simultaneously from different heights, are a solution from Zeppelin Systems with which large quantities can be mixed gently. The significantly higher throughputs also require other conveying concepts.

At this point, at the latest, it becomes clear that mechanical processes cannot usually be completely planned on the digital drawing board despite modern design methods such as computational fluid dynamics (CFD), modelling or simulations. Manufacturers of plants and machines are therefore increasingly investing in their own laboratories and test facilities in order to find the best process for a bulk solids application. New solutions are developed in close cooperation between machine and plant suppliers and the users. This is all the more important because - as the example of battery gigafabs shows - methods and processes that have not yet been fully developed are increasingly being scaled up to an industrial scale in "first-of-its-kind" plants.

**Sustainable food requires new processes**

The fact that joint development efforts are becoming increasingly important also applies to the food industry, which is also undergoing a transformation process. Resource conservation and sustainability are the megatrends here that are driving the need for new processes. This becomes clear, for example, in the trend towards meat alternatives, plant proteins and milk substitutes. These will also become increasingly important in the coming decades because the classic production of animal proteins is reaching its limits in view of a growing world population and changing eating habits. Here, too, mechanical processes play a central role - from grinding and sieving to centrifugation, filtration and drying to the texturisation of meat substitutes by extruder. Innovations are also created here through interdisciplinary cooperation between food technologists, mechanical engineers and process engineers.

**It won't work without automation and digitalisation**

Although it seems undisputed that AI or machine learning will play an important role in the process industry in the future, they are only one manifestation of digital technologies that can provide benefits in mechanical process engineering in the future. Two major trends are the increasing degree of automation and the need for modular plants. The basic idea: plants constructed from individual basic process units or modules make it possible not only to simplify engineering, but also to flexibly expand plant capacity. Processes can also be continuously optimised by evaluating process and sensor information.

Because the interconnection (orchestration) of such modules in the classic approach of process automation generates a high engineering and programming effort, a paradigm shift is necessary. This is currently taking place with module automation. The goal: in future, basic process operations and modules should be able to be combined with each other easily and without great programming effort. Because the modules already bring their control logic with them in the form of a Module Type Package (MTP) and have a standardised interface, the functions of the module can be used by the central control system as a service - and without any additional effort for control programming in the control system. This is a challenge for manufacturers of machines and plants in mechanical process engineering - they will have to deal intensively with questions of digitalisation, automation and control technology in the future. But more and more plant operators and machine manufacturers are convinced of the benefits - because consistent modularisation pays off in view of the shortage of skilled workers. The first suppliers, including the plant manufacturer GEA, are already rising to this challenge and offering new package units with MTP.

Conclusion: Whether battery technology, circular economy or sustainable nutrition - the technical challenges are enormous. Mechanical processes combined with digital technologies play a decisive role and are a central key to sustainability. Exciting questions, meaningful tasks and actively shaping a sustainable future - there is no lack of coolness factors in mechanical process engineering.

*Author: Armin Scheuermann, chemical engineer and freelance trade journalist*

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