ÖWGP
Österreichische Wissenschaftliche
Gesellschaft für Produktionstechnik

NEW DEAL
IN PRODUCTION

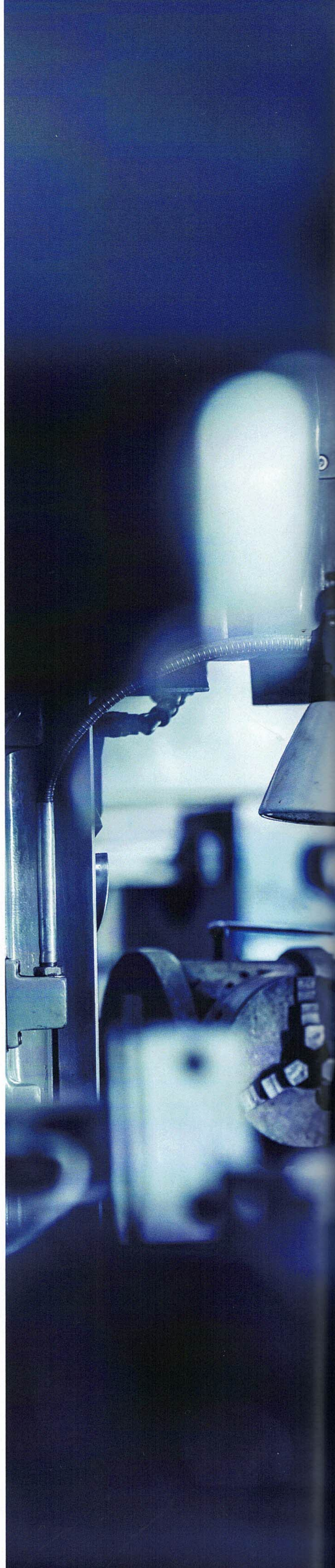
2. Production Systems

Fritz Bleicher, Franz Haas, Andreas Otto, Klaus Zeman

The current process of change in production – with its goal of intelligent machines as elements of the "Smart Factory of the Future" – is driven by the availability of technological innovations coupled with powerful communication technology and data management.

Milestones of production technology have always been closely linked to societal development and economic history. In preindustrial times, the prosperity of a society was determined by its level of proficiency in craft processes. Invention of the steam engine led to the first industrial revolution and laid the foundations for the development of modern production machinery. The ensuing increased use of iron-based materials spurred rapid advances in machining and forming technology. The second industrial revolution led to production based on the division of labour (e.g., assembly line production), and the third used the achievements of microprocessors in CNC technology for automation and robotics.
The resulting potential for applications in production engineering has increasingly been tapped and has already given rise to current topics such as "Industry 4.0", "Digital Transformation" and "Smart Production and Services".

Today, technological challenges arise not only from the development and use of new materials and from information and communications technology (ICT), but also from the increasing importance of sustainability and ecological aspects, for example, in individual mobility. In this context, the "Green Deal" is often discussed, especially at the political level.
These developments are currently being overshadowed by the global coronavirus pandemic and the associated economic crisis. Cities devoid of people, universities without students, an abrupt end to international passenger air traffic and a negative oil price in April 2020 are just examples of the immediate consequences of severely restricted public life. The 2008 financial crisis and the current COVID-19 crisis show us how vulnerable our sophisticated economic systems are to such disruptions. From a system-theoretical point of view,

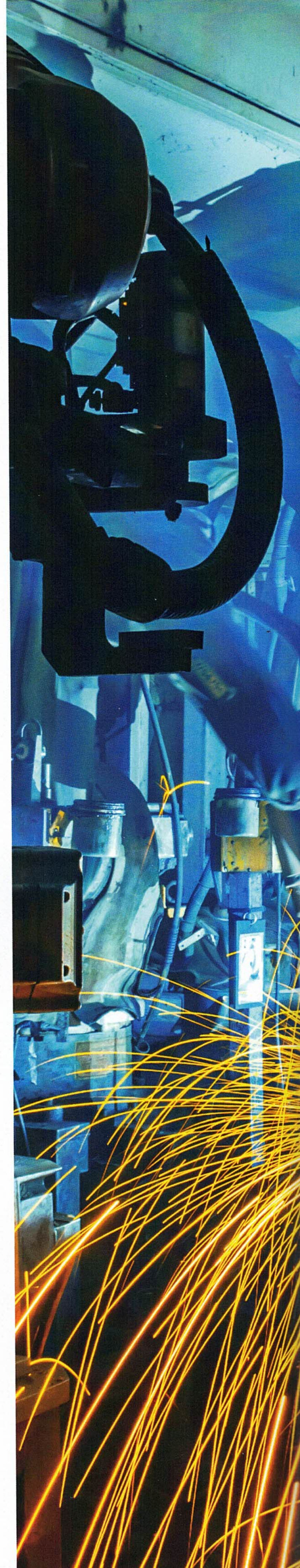


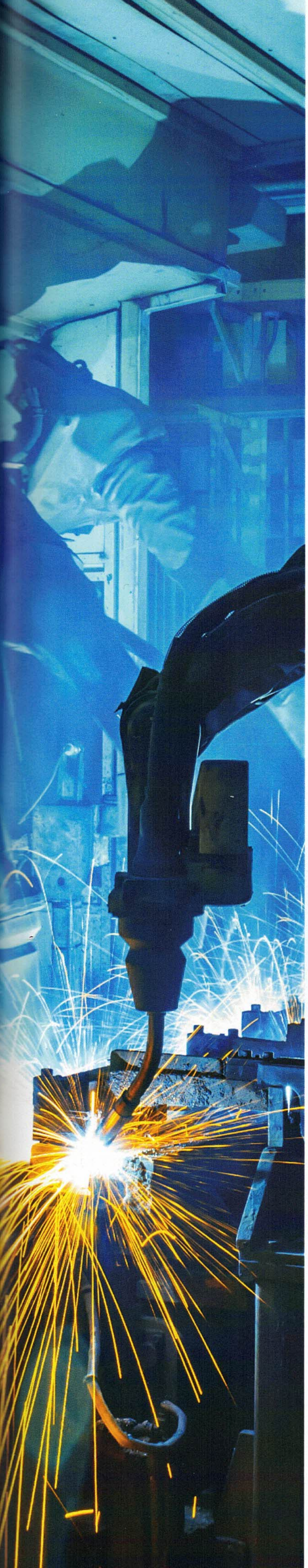
this is unsurprising, as it has long been known that highly optimised systems are particularly sensitive to imperfections. This means that a minimal change to a system can lead to a (qualitatively) completely altered behaviour, and this applies to production systems as well as economic and social systems. Crises and cuts in the economic performance of numerous industries are leading increasingly to discussions of sustainability and of resilient economic models. The present section reflects on the current situation from a technological point of view and risks a glimpse into the future. ■

2.1. Adaptable and autonomous production systems

Despite the continuous development of new production technologies, classic manufacturing processes such as casting, sintering, forming, machining and welding remain central to the value chain and must also be developed further.
In machining technology, new cutting materials and coatings in conjunction with optimised control strategies enable a significant increase in productivity. Due to their resistance to chemicals and high temperatures, cutting materials based on ceramics offer up to 50 times the cutting speed of those based on hard metals. In the field of components, non-iron-based alloys (e.g., titanium alloys and high-temperature superalloys) and compositae materials are difficult to machine, and their processing is simplified, for example, by tools with CVD hard coatings. Model-based methods are used increasingly to optimise tool geometries. Cutting tools, comprising cutting edge and tool holder, are becoming very complex technological systems: Sensors and actuators integrated within the tool holders offer great potential for optimising and increasing the flexibility of manufacturing processes. In this context, additive manufacturing is also growing in importance, as it enables, for example, the production of complex cooling lubricant systems in tool holders and thus opportunities for topological optimisation and weight reduction. These trends also guarantee Austrian industry a leading technological role in primary shaping and (metal) forming processes or in joining technologies, where, for example, conformal design of heating or cooling channels enables process capability and productivity to be improved. Integration of sensors allows monitoring mould-filling behaviour and effects in forming processes, such as cutting impact.

Photonic technologies, now an accepted standard, benefit themselves from current innovations in laser technology. Pulsed high-power laser systems with an average power in the kW range and pulse durations in the femto- and picosecond ranges enable cost-efficient and flexible processing for functionalization of large surfaces with minimal heat input; thus, tribological, optical and fluid dynamic effects can, for instance, be achieved. In addition, these pulsed systems allow heterogeneous materials such as fibre-reinforced plastics to be processed delicately and with high precision.
New types of laser systems in which the spatial and temporal distributions of beam intensity can be controlled purposefully allow, for example, in laser-beam welding a significant reduction in – or complete avoidance of – processing errors while increasing the achievable processing speed. Despite various ongoing European research projects focusing on these innovative laser systems, their potential – especially in terms of process and material flexibility – is far from being fully understood and realised. Particularly in laser-assisted additive manufacturing processes, these developments open up new possibilities for controlling heat introduction and thus for improving component properties.
As additive manufacturing has matured, it has developed into a key general technology in modern production that opens up completely new possibilities, especially in product development and design: for instance, novel lightweight constructions and energy-efficient cooling systems that use new materials and can be produced only by additive manufacturing.
Additive manufacturing processes will also play a crucial role in the effort to make production more flexible; they will surely not replace established manufacturing processes entirely, but will





expand the range of available manufacturing technologies. Their true potential will be tapped in synergy with other processes, for example, in hybrid machines. Deficiencies of additively manufactured components in terms of achievable surface quality and dimensional accuracy can, for instance, be compensated for by subsequent machining.
Further, the high costs of purely additively manufactured components can be reduced by combining additive and conventional processes in one machine. Clearly, this also requires the development of appropriate software tools that enable optimal planning of hybrid processes considering the potential of each technology used.
The development of hybrid machines in which several ("additive" and "subtractive") manufacturing processes are combined is an important trend in machine tool flexibility.

Even further reaching are innovative concepts for flexible, modular, adaptable and reusable production systems, which will in future increasingly replace capital-intensive means of production designed and built for only one specific task.
Central issues in the development of these production systems are the control technology used and its programming, information and communications technologies, self-organisation and self-optimisation, the degree of flexibility of the system architecture, and stability and optimality of the control of resource and energy consumption. On this basis, the demand from volatile and complex future markets for innovative, highly flexible and economical manufacturing technologies and production systems can be met.

Integration of sensors, real-time data analysis and feeding back of results into the manufacturing process enable manufacturing systems to take on aspects of quality assurance already during processing (in process). Thus, the risk of loss due to rejects seen in the prevailing ex-post quality assurance method is reduced, and the resource efficiency of production can be increased. En route to these integrated systems, a trend has emerged in production metrology and quality assurance towards 100% workpiece inspection within the production machine (in situ) and directly in the production line with feedback to process control (in line) or random sampling at the production machine (at line). Classic random sample measurement is increasingly becoming obsolete, as measuring devices take on the role of reference test equipment and calibrate or validate quality assurance algorithms in the integrated systems described above. In combination with data evaluation technologies and Artificial Intelligence, these algorithms will control more complex relationships, which will ultimately enable self-learning and self-optimising manufacturing systems. Precision engineering in toolmaking, the semiconductor industry and optics remains an exciting field of research with great potential for future sustainable production. ■

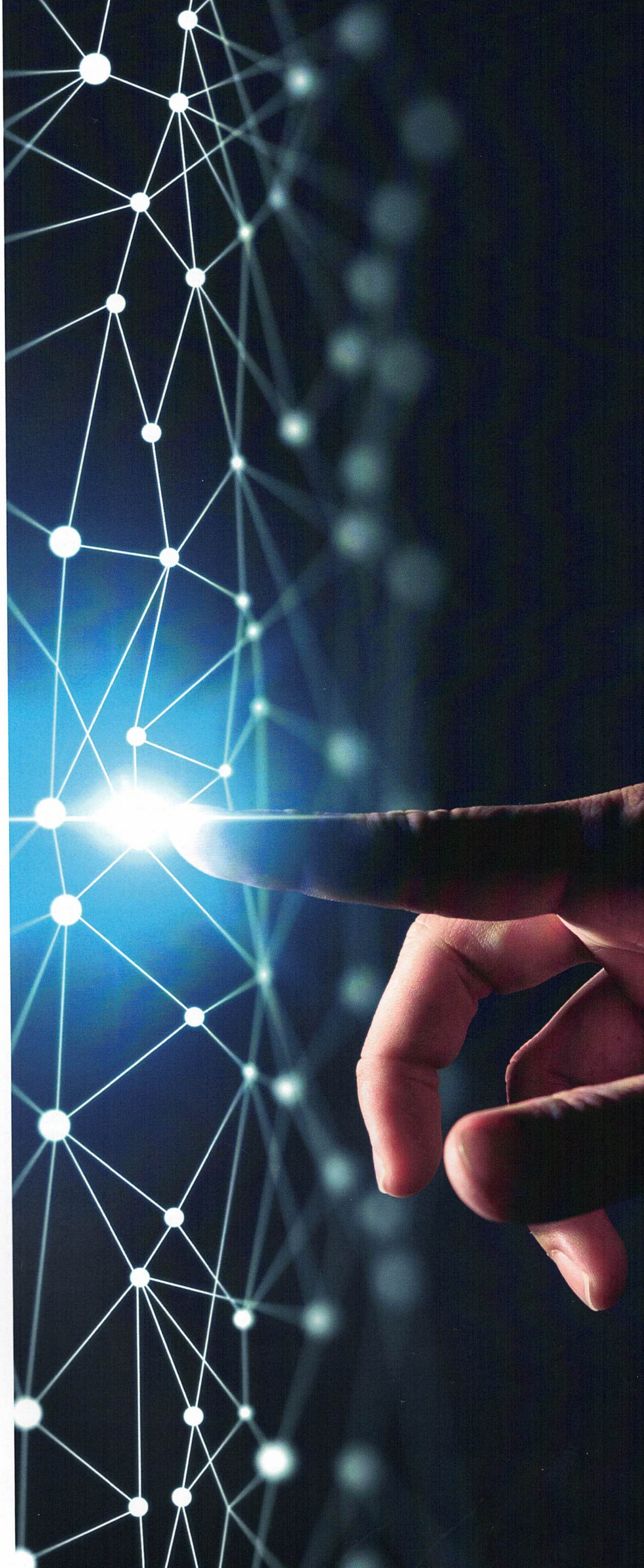
Classic manufacturing processes will continue to be of central importance in production and must be further improved. This also applies to photonic technologies, the potential of which is far from being exhausted.

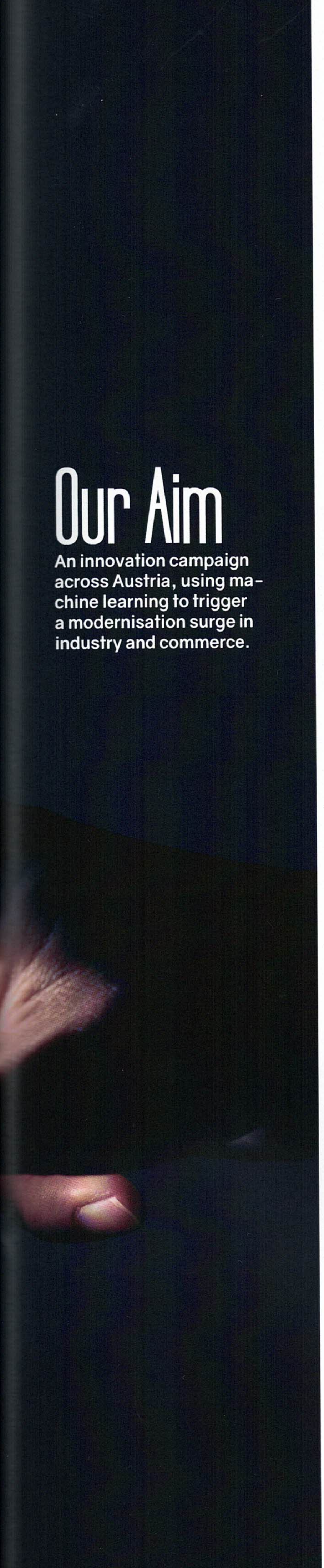
Additive manufacturing is now a key technology in modern production.

Modern production will be shaped by autonomous, modular and adaptable production systems that will replace inflexible and capital-intensive production lines.

2.2. Digital Transformation

Studies have shown that Austrian workers do not generally expect to be replaced by artificial-intelligence-based technologies. However, AI will undoubtedly change most job profiles, and its advantages outweigh its disadvantages. In production, AI algorithms are increasingly used to optimise processes and to analyse data. The aim of this current development should be an innovation campaign across Austria supported by numerous new products in machine and plant construction that have been improved by machine learning. In parallel, a completely new generation of automation technology could lead to a modernisation surge in industry and commerce. Autonomous production overnight using automated loading of machines with workpieces is becoming increasingly common: Production runs in night shifts keep capacity free in the day for individual parts and short runs. The lean automation programme for cost-effective automation of machine tools is another contemporary example.
Automated Guided Vehicles (AGVs) have become an integral part of modern production. Interacting with a fleet management system for central control of several "shuttles" with heavy payloads and longer charging intervals, AGVs are proving to be the pacemakers for agile production of the future. Recently introduced location technologies enable use of driverless transport systems and drones in production, with integrated monitoring of the supply chain via ultra-broadband, RFID, 5G and GPS. The underlying idaea is system openness for flexible configuration of complete systems.





Our Aim

An innovation campaign across Austria, using machine learning to trigger a modernisation surge in industry and commerce.

In addition to various aspects of digital transformation in all phases of the product life cycle – that is, from the first product idaea to product development, production, distribution, use, service and replacement – the relationship between manufacturer and customer is gaining in importance. "Classic" industries will increasingly deploy and use technologies that are based on the Internet of Things and data and online services. The associated real-time networking of products, processes and infrastructure will permanently change the working world of the future. New challenges thus arise from the increasing flexibility and complexity of production systems and of internal logistics.

The hitherto prevailing interpretation of Industry 4.0, according to which networked production resulted from linking manufacturing solutions and IT, is being expanded – or replaced – by agile, self-learning systems.
Manufacturing systems will have the ability to programme and organise themselves, will impose new requirements on themselves, and will adapt and optimise themselves. This requires research, primarily into new approaches to the integration of various control and communication systems (breaking up the common automation pyramid), technologies for safety and IT security, and development and adaptation of information interfaces and data semantics. Further, interdisciplinary virtualization of processes, machines and procedures is gaining in importance in this context. The development and use of multi-physical, coupled simulation models to master growing system complexity is coming increasingly to the fore. Machine learning and AI methods will play a decisive role in the use of information in future production systems.
Particular attention must be paid to the transferability of established information systems and solutions for future uses. Complete penetration of value creation processes by integrated information systems and cross-system optimisation methods is key to resource-saving production. ■

> Artificial Intelligence and machine learning will trigger a modernisation in industry and commerce and will change many job profiles in the long term.
>
> Mastering the growing complexity of new types of production systems requires the development and use of multi-physical, coupled simulation models.
>
> Sustainable and resource-saving production requires integrated information systems and cross-system optimisation methods to completely penetrate value creation processes.

2.3. Contribution of Production to the Green Deal

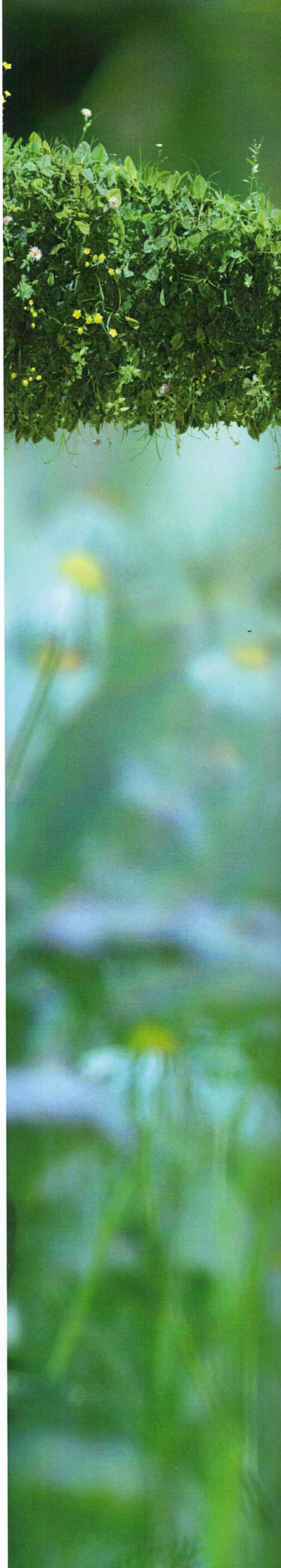
In her role as President of the European Commission, Ursula von der Leyen has laid out the strategic goals. By 2030, greenhouse gas emissions are to be reduced by 50% compared to 1990, and by 2050 the EU is to be completely climate-neutral. This can only be achieved by extensive restructuring of all economic sectors. In the context of industrial production, the "Green Deal" entails a strategy of circular economy with significantly reduced use of resources and systematic reusability of products via intelligent upcycling and recycling. Closing of energy and material cycles is a prerequisite for the circular economy. The Association of German Machine Tool Builders (VDW) sees an opportunity to develop new revenue streams in the process of analysing how the ambitious goals of CO_2 reduction might feasibly be achieved. The VDW considers digital networking using new business models to be the greatest driver towards achieving goals. This is also evident in the sustainability of steel production (decarbonisation) and the innovative use of hydrogen as an energy source. Following the hydrogen path, from hydrogen generation via its distribution to its application in mobility, requires joined forces.

The new industrial and consumer goods necessary for sustainable energy supply, distribution and use must also be produced. Particularly in Austria and in Europe, this will in some regards necessitate disruptive redesign of production facilities to form new value-creating centres and networks for ecological production. This requires mastery of complex causal relationships and use of newly conceived closed material cycles. Society must immediately launch focused innovation programmes in order for implementation to achieve the proclaimed goals. ■

The medium- and long-term climate goals of the EU - including complete climate neutrality by 2050 - can only be achieved via far-reaching restructuring of all economic sectors.

This requires – in part – disruptive redesign of production facilities, mastery of complex causal relationships and use of newly conceived closed material cycles.

Focused innovation campaigns must be launched immediately if implementation is to attain the climate goals proclaimed.



www.oewgp.at

Imprint
Österreichische Wissenschaftliche Gesellschaft für Produktionstechnik (ÖWGP), Vienna
Print: Froschauer Druckerei und Fotografie, Leonding

International Edition