Fraunhofer IPK

Fraunhofer Institute for Production Systems and Design Technology IPK

Solutions from Research and Development
2024 / 2025

Human-Centered Resource-Efficient Resilient

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Researching for You

»What challenges does industry face?« This was the central question guiding the »Research and Development Trends« issue as we discussed future technology and innovation needs in manufacturing with executives from a variety of industries. Despite industry-specific differences, the overall result was homogeneous: The manufacturing of the future is data-driven, but there is still a lot of development work to be done to get there. Against this backdrop, we focused on our interviewees' assessments of the state of technical and methodological development as well as the tasks ahead in their respective industries, and discussed the assignments for our institute that could be derived from this.

This time, we switch perspectives: We invite you to look over our shoulders and see us at work. We present R&D projects and solutions which provide answers to industry's most pressing questions. We will show you how our researchers transfer digital, networked technologies into industrial applications, how they curate large amounts of data using machine learning and artificial intelligence, and how they develop applications on this basis. The spectrum ranges from lifecycle management for sustainable products, to comprehensive system integration, control functions that increase the energy efficiency of machines, and assistance systems to support employees on the shop floor.

Our interdisciplinary teams are uniquely positioned to address these issues across domains. They include mechanical engineers, economists, electrical engineers, computer scientists and bioengineers, who cooperate strategically. They combine production expertise with strong digital skills and think outside the box of their respective disciplines to bring together technologies and methods that were previously thought of separately. In this way, they create integrated system solutions for our customers and partners. A good example are production systems in which humans, machines and systems interact as partners to increase flexibility, productivity and resilience.

Discover the broad portfolio of our research and development and do not hesitate to contact us with your own research request.

PROF. DR. H. C. DR.-ING. ECKART UHLMANN
Director

Making Manufacturing Flexible

For the 2022/23 edition »Research and Development Trends«, we asked managers of well-known manufacturing companies what challenges and requirements they expect to be faced with in the coming years. The result was clear: Technologies for five topics dominated the discussions across all industries. Our scientists are tackling these areas in application-oriented research projects.

We Make Production Fit for Change

Volatility shapes today's manufacturing industry. In early 2020, climate change was considered the biggest challenge for production. Since then, various international crises have disrupted established production structures. Location conditions and supply chains have changed radically. The shortage of skilled workers and international competition are also increasing pressure on companies to rethink their methods, processes and technologies. Resource efficiency, regulatory requirements and demographic change demand flexible, sustainable approaches that promote corporate resilience.

From large to small scale: a holistic perspective on industry

Consequently, our research focuses on five overarching topics that concern companies across all industries:

- Data management, networking and analysis
- Manufacturing systems and production control
- Intelligent mechatronic systems technology
- Knowledge and assistance in production
- Sustainability and environmental compatibility

The challenge of collecting data, storing it appropriately, transferring it securely and evaluating it intelligently is the starting point for many development activities in industry. The great attention that data is currently receiving is not an end in itself. The idea behind it is that data-driven solutions make processes more efficient and enable new business models.

The right basic methods make solutions for all process levels conceivable. At the level of overarching process control, production systems can achieve reliable throughputs without takt and assembly lines. To make sure that each machine can play its part in such a scenario, the individual systems must be equipped with a certain amount of intelligence. Assistance systems can in turn be based on this and support machine operators in setting up processes as well as during maintenance work. However, data-based solutions can also contribute in other ways to preparing manufacturing employees for changing tasks. And data holds great potential when it comes to implementing sustainability and environmental compatibility as well. Interactions between these areas make it necessary to holistically approach concepts for production.

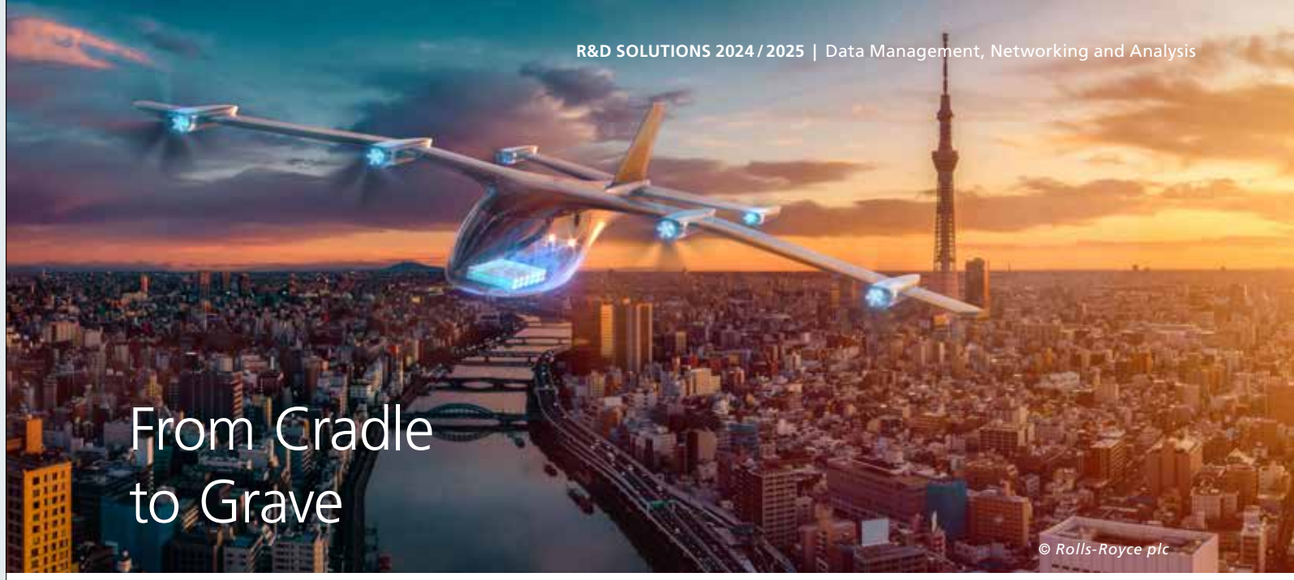
This is precisely where we see our role. With integrated solutions and technologies, we help to increase our customers' and partners' competitiveness and ability to handle crises. In this issue, we present our approaches and results.

Data – An Invaluable Goldmine

Industry is convinced: Working securely and efficiently with data will be crucial for companies to succeed. Data-driven solutions make processes more efficient and generate new business models. Our experts develop strategies and solutions for working with this valuable raw material.

Everyone seems to be talking about data. It already forms the foundation of many industrial processes – and its importance will only continue to increase. The efficient management of customer and product data determines how successfully orders can be fulfilled or how well products can be developed across product generations. Machine tools, previously closed technical systems, are equipped with sensors that monitor ongoing processes and machine status. When data is networked, intelligently analyzed and integrated into higher-level systems, it provides the basis for comprehensive management of industrial processes from product development to shop floor and sales. When it is made accessible even beyond company boundaries, data enables a truly circular economy: If the components and materials contained in a product are made transparent to a dismantling business, then decisions about recycling or refurbishment can be more informed – and raw materials or entire products can be kept in use for longer.

R&D projects at Fraunhofer IPK deal with all of these approaches. Product data management across the entire life cycle is just as much a part of this as the development of digital twins. These virtual representations of products, processes and systems mirror their structure and behavior and introduce unprecedented levels of transparency into industrial processes. Data-based solutions also help to overcome communication barriers between domains within a company and to integrate processes across entire businesses.



From Cradle to Grave

© Rolls-Royce plc

The relevance of product data has increased massively: Products are now being monitored from engineering through use to remanufacturing or recycling.

With the transition to a circular economy, the increasing importance of product-accompanying services and the further rollout of electric and autonomous mobility, expectations on continuous product data management have increased considerably. Data is collected and evaluated from the development stage all the way to the end of life of a product. The resulting insights are in turn incorporated into the intelligent engineering of the next product generation. To this end, data from a wide variety of sources such as IT systems, platforms or databases must be collected and linked to each other. They can only be made accessible consistently across all possible applications if the different data formats and models are standardized and exchanged in a seamlessly linked way – cross-company IP-security included.

Electrifying the aviation industry

Why is all this necessary? For example, to support the establishment of electric air travel: By moving away from fossil fuels, flying will become way less emission-heavy. In order to enable this, aircraft manufacturers need new concepts based on data-based models: »The drive distribution has to be rethought, which changes weight distribution and aerodynamics,« says Dr. Kai Lindow, head of the Virtual Product Creation division at Fraunhofer IPK. »However, many additional aspects must be included when developing electrified aircraft: From testing to new business processes, contracts and regulations, everything has to be mapped and integrated.« In projects with companies such as Rolls-Royce and Chesco, as well as the German Aerospace Industries Association, our researchers are therefore developing holistic lifecycle concepts.

Continuously efficient in all areas

Continuous data management unlocks new possibilities in other areas as well. In collaboration with industry partners, our researchers developed a powerful digital networking platform that enables manufacturing companies to manage energy efficiency in innovative ways. The platform not only integrates operational but also structural data, such as system topologies or model libraries.

Our researchers are breaking new ground in the qualification of welded components by linking data from different types of simulations – such as welding and forming simulations – which do not have any interfaces. This makes it possible to virtually simulate the behavior of complex components with different materials and sheet thicknesses and avoid resource-intensive experiments.

More information

www.ipk.fraunhofer.de/gaia-x-en

www.ipk.fraunhofer.de/eneffnet-en

Contact

Dr.-Ing. Kai Lindow
+49 30 39006-214
kai.lindow@
ipk.fraunhofer.de

Digital Twins at a Glance

Digital twin technology is now mature enough to unlock new possibilities for all kinds of industries. Many companies want to harness this potential but do not quite know where to start. To give you an overview of the topic, we present the different types and levels of digital twins on this page and give examples of research questions that we are working on at Fraunhofer IPK.

More information
www.ipk.fraunhofer.de/industry-trend-digital-twins

R&D SOLUTIONS 2024 / 2025 | Data Management, Networking and Analysis

Industrial Metaverse

The industrial metaverse creates the interface between the physical and virtual world in the production process. We are exploring ways in which people can interact directly with digital twins using extended reality methods, for example during process planning or in collaborative design reviews.

Contact
Dr. Maiara Rosa Cencic | +49 30 39006-417
maiara.rosa.cencic@ipk.fraunhofer.de

Product twins

Product twins are digital representations of real, individual assets. They contain data across the life cycle and provide insights into product behavior and optimization potentials. With their help, data can for example be exchanged between companies. Products can be planned proactively as well as monitored and optimized in all phases of their life cycle, for instance regarding their ecological foot-print or energy efficiency.

Contact
Theresa Riedelsheimer | +49 30 39006-219
theresa.riedelsheimer@ipk.fraunhofer.de

Technology, machine and system twins

Digital twins of manufacturing technologies, machines and systems reflect the current status during production. This allows us to record and control the energy efficiency of production systems automatically or identify the need for servicing early on and support maintenance with the help of context-sensitive assistance tools.

Contact
Claudio Geisert | +49 30 39006-133
claudio.geisert@ipk.fraunhofer.de

Process twins

Digital process twins connect factory operations with corporate business processes. This allows us to examine systems as a whole and gain important insights, for example for production planning or business models, based on a solid foundation of data.

Contact
Prof. Dr.-Ing. Thomas Knothe | +49 30 39006-195
thomas.knothe@ipk.fraunhofer.de

Digital Throughout

The software industry led the way: Development, planning, introduction and manufacturing of products are considered and managed together from end to end (E2E).

Scientists at Fraunhofer IPK are researching how E2E digitalization in production can succeed in the project »From conventional production plant to resilient competence plant by means of Industry 4.0 (Werk 4.0)«. Together with 12 partners, including Mercedes Benz AG, TU Berlin and Werner-von-Siemens-Centre for Industry and Science e.V. (WvSC), they are developing flexible production solutions that enable manufacturers to react more quickly to technological developments and new market requirements.

The basic idea is that development, planning, launch and production are no longer regarded as organizationally separate units that operate sequentially or in parallel. Instead, they are designed and managed together as functions from start to finish (E2E). This should enable manufacturing companies to adapt processes more flexibly in future, develop products more quickly and make their production more resilient overall.

Translation work is required for end-to-end digital process chains of this kind: »Every simulation, robot or in-house software has its own language,« explains robotics expert Jan Kuschan. His task is to develop a language to describe process and operating sequences with clearly defined interfaces through which different software tools can exchange data and communicate with each other. The goal is to automatically translate orders into machine programs and thus enable more variant flexibility. »If a component is modified during the assembly process and the underlying programs are adapted directly, manufacturers can also produce smaller quantities in more variants without the need for a completely new setup each time,« says Kuschan.

Dr. Maiara Rosa Cencic and her team's job in the Werk 4.0 project is developing an augmented reality assistance system to support workers with manual assembly tasks. The AR assistance system visualizes the individual steps and guides workers during assembly. »We are currently using expert surveys and focus groups to determine the optimal projection methodology for the AR application,« says the extended reality specialist. »Because whether AR glasses or table projection – employees should enjoy using the assistance system over a longer period of time without any strain.«

Funding notice

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Contact

Jan Kuschan
+49 30 39006-205
jan.kuschan@ipk.fraunhofer.de

Dr. Maiara Rosa Cencic
+49 30 39006-417
maiara.rosa.cencic@ipk.fraunhofer.de

More information

www.ipk.fraunhofer.de/werk-40-en

wvsc.berlin/en/projekt/werk4-0

Data in Dialogue

Manuel Bösing, digital production specialist, and Paul Koch, expert in automation, discuss how the most important corporate resource can be used.

Images

Paul Koch (top) and Manuel Bösing (bottom) develop production technology solutions that depend on curated data.

More information

www.ipk.fraunhofer.de/kikerp-en

www.ipk.fraunhofer.de/mro-ii-en

<u>How are you using data and AI?</u>
Koch A prerequisite for automation is often that machines need to be able to »see«. We teach them this skill – for example through using AI-based image processing. Thanks to deep learning, robots and machines can recognize increasingly complex patterns and solve ever more difficult tasks. The key to successful learning is optimally prepared data.

Bösing Data is the foundation for networked production. We analyze data down to the smallest detail to optimize machines, processes and maintenance. Smart maintenance is no longer a trend, but a necessity. And AI is also driving forward the evaluation of machine data.

<u>From process analysis to AI projects: What role does data quality play?</u>
Bösing The challenge lies in identifying the data that is most meaningful for well-founded analyses. This is not always easy. Companies benefit from specific use cases that make it possible to grasp the potential of data solutions.

Koch Smart data before big data, I agree. By filtering large amounts of data with the help of special algorithms, we can significantly reduce the amount of training data. The results are more precise AI models and a better energy footprint.

<u>What are you currently working on and to what extent does it involve data?</u>
Bösing We need a sophisticated network to allow all devices on the shop floor to communicate with each other. As part of the MRO 2.0 project, we are developing a multilayer infrastructure consisting of edge, fog and cloud. Each layer is responsible for one aspect of data processing. We also want to create a truly end-to-end digital component twin using a gas turbine blade as an example.

Koch In the project KIKERP (see p. 51) we are developing an AI assistant that evaluates old electrical appliances for refurbishing. Until enough image data is available, we are generating artificial training data that resembles the real data – also using AI. At the same time, we are researching how purely synthetic data can be used to train for an optical inspection – even before the very first product has been manufactured. This reduces costs and ensures high quality right from the start.

Contact

Manuel Bösing | +49 30 39006-186
manuel.boesing@ipk.fraunhofer.de

Paul Koch | +49 30 39006-436
paul.koch@ipk.fraunhofer.de

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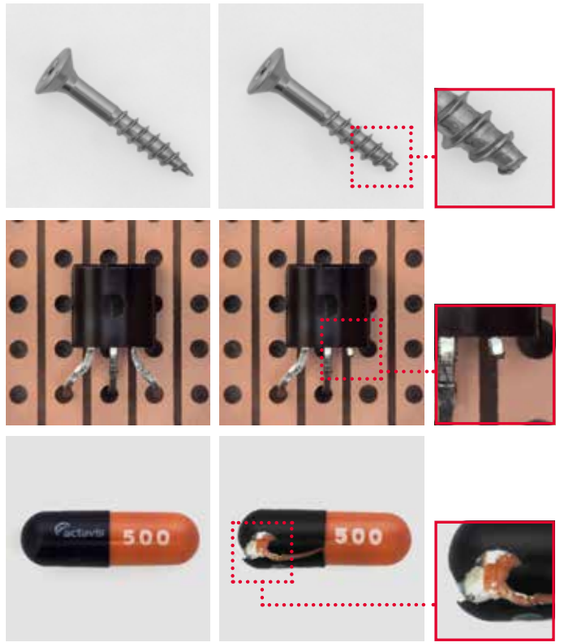


Image

Detection of defective screws, transistors and encapsulations
© MVTec Software GmbH

AI-SUPPORTED OPTICAL INSPECTION: EFFICIENT AND RESOURCE-SAVING QUALITY ASSURANCE

Anomaly detection plays a key role in quality assurance within modern production processes. In contrast to conventional methods, which aim to identify all potential defects in advance, Fraunhofer IPK pursues an innovative approach: We determine what the ideal image of a product should look like using high-quality »good data«, defining the correct parameters of a product without defects. All products that do not meet these parameters are then recognized as a deviation – and therefore defective – during an automated optical inspection.

This approach requires less data and makes it unnecessary to provide examples for each possible defect case. It also means that there is no need to produce a large number of defective products to train machines to distinguish between acceptable and unacceptable conditions.

This methodology is not only efficient in detecting new types of defects, but also significantly reduces the effort required for implementation. The detected anomalies can be used to effortlessly train for defect classifications that occur further downstream. As a result, this anomaly detection enables efficient implementation and a fast response to individual errors.

Contact
Martin Pape
+49 30 39006-465
martin.pape@
ipk.fraunhofer.de

02

5G REMOTE CONTROL: OPERATING PRODUCTION SYSTEMS WORLDWIDE FROM YOUR OFFICE

Where WiFi-based networks reach their limits in terms of bandwidth, latency and capacity, 5G is just getting started. These properties have made 5G essential when managing industrial data and controlling production systems remotely. 5G networks enable time-critical transmission of sensor data and commands for real-time control by remote servers – basic requirements for cloud-controlled robotics.

The scalable computing power of the cloud enables complex data analyses that were previously impossible due to local computing limitations. Cloud technology in combination with 5G thus unlocks the full potential of sensor data and optimizes system performance.

At Fraunhofer IPK, we develop the necessary algorithms and systematically test application scenarios in order to prepare companies for the use of 5G with practical insights and preliminary studies. One of the ways we demonstrate the versatility of 5G in the production environment is a mobile robot platform. A lightweight controller sends data directly to a cloud infrastructure via 5G. The data is then processed into control commands in real time.

Contact
Moritz Chemnitz
+49 30 39006-127
moritz.chemnitz@
ipk.fraunhofer.de

03

CONTINUOUS IMPROVEMENT: INTEGRATED DATA, SMART TEAMS

The process of continuous improvement (CIP) forms the foundation of modern management. Within frameworks such as lean management and total quality management, CIP aims to continuously optimize all processes with the involvement of employees.

A clearly defined improvement process establishes responsibilities and ensures the comprehensive recording of optimization potentials. A central aspect is motivating and supporting employees. Technical tools like the CIP tool assist them in selecting and implementing suitable methods that seamlessly integrate into the existing management system. Additionally, employees can capture and process all relevant data throughout the process in one tool. By integrating various types of inputs, synergies are identified, and alignment with long-term corporate goals is simplified, ensuring that each improvement purposefully advances the company. Successful improvements are fed back into new projects, ensuring systematic knowledge transfer.

Our process provides a step-by-step approach: We start with an analysis of the current situation to determine necessary action points. We then define a target process, identify the necessary inputs for the CIP and use these for quick-win projects.

At the same time, we promote the employees' skills through training and coaching in order to firmly anchor the CIP in the company. Our approach is flexible and supports the transition from the implementation through to the consolidation of a management system, ensuring that companies remain competitive in the long term.

Contact
Konstantin Neumann
+49 30 39006-139
konstantin.neumann@
ipk.fraunhofer.de

Manufacturing Systems and Production Control

Manufacturing Efficiently with Flexible Processes

Fast throughput is only possible within rigid production structures? That was yesterday. The manufacturing systems of today are modular and can be recombined time and time again – data-based digitalization makes that possible. In the future, resources in manufacturing will even »think« along with empathy.

Agility is in high demand in today's production. Companies have to adapt their manufacturing to ever-changing conditions. On the one hand, individual customer requirements have become part of everyday life, even in the classic series production business. Some companies operate with 50,000 system products at annual repeat rates of 1.4. On the other hand, global conditions that disrupt supply chains, for example, make it necessary to frequently restructure production processes.

Flexible adjustments are hardly possible in traditional production structures where firmly integrated production steps interlock – but they are certainly feasible in modular, digitally networked systems. In the factory of the future, network nodes are as important as machine chucks – because integrating systems into end-to-end manufacturing processes is purely IT-based. This way, machines, robots, mobile equipment and even manual workstations can be rearranged into ever changing sequences. The production environment thus becomes product-agnostic as a result, allowing the cost-effective conversion to different product variants, even in small quantities. Cockpits and similar solutions for process control provide the necessary overview.

When it comes to developing flexible manufacturing environments, Fraunhofer IPK goes one step further: The Fraunhofer lighthouse project EMOTION aims to realize production scenarios in which all players, whether human or machine, independently identify malfunctions, bottlenecks and overloads and react to them with empathy.

Digitalization Is Expensive? Hardly So!

A key demand in production is flexibility – that much is clear. But how can it be implemented economically? One possible answer is a company model developed by Fraunhofer IPK.

Pandemics, wars and disruptions in the global economy are putting pressure on companies worldwide. How can businesses react quickly and appropriately without driving up the prices of their own products and thus wiping themselves off the market? One of the largest electrical appliance manufacturers in the world, headquartered in China, asked themselves this question. They brought Fraunhofer IPK on board to find a solution to their challenges. That was five years ago. »It is not enough to simply relocate production to other countries – rather production itself has to be set up differently,« summarizes Prof. Holger Kohl, head of the Corporate Management division. »It is about modular, flexible and automated production, that, for instance, allows you to switch from manufacturing an angle grinder to producing a drill within a very short time span, as well as reacting just as quickly to global changes.«

Extensive automation – low product costs

In order to realize this for their client, researchers at Fraunhofer IPK started by developing a company model called the »Blue Print Plant Model«. It provided the basis for automation – with no changes to the product costs. »Here, we represent the entire disciplines of planning and control, purchasing, supplier management to the customer, employees and production management as well as automation, based on a core model,« explains Jan Torka, who spearheaded the technical implementation. »We can immediately see how changes affect product costs in this model.« The special feature: Contrary to conventional paradigms, the optimal product costs can be achieved with the highest degree of automation. »Digitalization does not have to be expensive,« concludes Prof. Kohl.

Pilot plant: 45 percent automation

Based on the model, a pilot plant for the assembly of eight different electric power tool types was developed, each with up to 1000 variants. It is now in operation at the Chinese partner company – and achieves a degree of automation of 45 percent. By comparison, the standard in this particular product environment is around ten percent. The pilot plant can be used to manufacture circular saws as well as drills and other products of comparable size. At the same time, it was possible to reduce the changeover time from two and a half hours to just ten minutes.

Image

Development environment for modular, flexible automated production at the customer's premises

More information

www.ipk.fraunhofer.de/integrated-modular-factory

Contact

Prof. Dr.-Ing. Holger Kohl
+49 30 39006-233
holger.kohl@
ipk.fraunhofer.de

Jan Torka
+49 30 39006-156
jan.torka@
ipk.fraunhofer.de

»Smart« Is Old News – Make Way for Empathy

Human-technology solutions for the resilient production of tomorrow are created in the project EMOTION. Their key concept is empathy.

Imagine a factory in which machines not only perform tasks, but also recognize what the various actors in their environment – other machines, humans and robots – currently need. A factory in which machines and robots independently identify faults, bottlenecks and overloads, and where they offer their help when necessary by adapting autonomously. Welcome to EMOTION – a Fraunhofer flagship project that aims to strengthen the resilience of manufacturing companies in the face of crises and disruptive developments.

Flexibility as a common mission

The core idea is this: In production systems, resilience arises from synergies in the interaction between people and intelligent machines. When the actions of all players seamlessly intertwine, they can react dynamically to unexpected events and learn from them. The result is an agile production system that skillfully navigates through turbulence and remains capable of acting even under harsh conditions.

What does it take? Empathy! »With EMOTION, we want to transfer the ability to empathize from humans to technical systems,« Christopher Mühlich explains. He is coordinating the lighthouse project in which seven Fraunhofer Institutes are working together. »In an empathetic production system, each component is not only aware of its own technical status, but also that of all other participants – and can react accordingly.«

Synergy in action

But theory only goes so far. A combination of the latest technologies from the fields of smart maintenance, machine learning, the Internet of Things and automation is required to equip production systems with these features. The developed solutions are then tested and refined further in close cooperation with industry. »At project presentations, we regularly experience growing enthusiasm as soon as we get to the specific applications,« says Mühlich. »Afterwards, there are often lively discussions about what the concept could make possible.«

To demonstrate some of these possibilities, Fraunhofer IPK is developing a complex practical scenario for the empathetic cooperation between technical systems based on a process chain for the production of fuel cells. »An overarching goal here is to closely integrate the areas of production planning and control as well as maintenance and production – an essential step towards a robust overall system.«

Safety first: data spaces

The human user is seamlessly integrated into the overall system as they receive individual support from the empathetic assistance systems. Their customized installation involves the processing of personal data, bringing up significant questions concerning the issue of data sovereignty. »Handling sensitive data is a topic that is understandably very important to companies,« says Mühlich. »We have therefore given a lot of thought as to how we approach this.«

The project partners have developed a solution that combines two innovative technologies to ensure that employees' privacy is not jeopardized: federated learning and data spaces. This gives each employee a virtual data space in which their data is only accessible to them. The AI approach of federated learning makes it possible to train models exclusively on this individual data when optimizing assistance systems or production processes. Only the models themselves – without the sensitive data – are then brought together at a central location. »This allows us to use the full potential of the available data while at the same time protecting personal information,« explains Mühlich.

> »With EMOTION, we want to transfer the ability to empathize from humans to technical systems.«

To be continued …

EMOTION has successfully completed its first year. The AI, data and hardware technologies that have been developed are being brought together in an overarching platform. Mühlich describes his role as a project networker as highly fascinating, albeit a lot of work. »We are starting the second year with lots of new ideas,« he sums up. »And we are getting closer to the vision of a completely self-controlling factory in which people and machines work together empathetically, step by step.«

More information

www.ipk.fraunhofer.de/emotion-en

Contact

Christopher Mühlich
+49 30 39006-144
christopher.muehlich@ipk.fraunhofer.de

Stable and Agile All at Once

Production processes should always be stable, but at the same time it is important to react flexibly to short-term changes. Deike Ihnen, researcher at Fraunhofer IPK, and Dirk Busse, Managing Director of budatec, explain how this can be achieved.

Agility versus stability – what does that mean for companies?

Ihnen Small companies such as budatec GmbH are inevitably very agile – after all, there is less room for standardization with fewer employees. In large companies like AZO GmbH, processes are generally standardized and rigid, and innovation can easily be left on the sidelines. In the AmbiProd project, we want to help large companies become more agile, while small companies take more advantage of standardization.

Busse In principle, we are approaching the challenge from two sides: the large companies from the stable, standardized perspective and us from the flexible side. The aim is to bring us closer together and learn from each other.

How can this be achieved in practice?

Ihnen We were inspired by how the police conduct situation reports, for example in the case of a hostage-taking. We are transfering this concept to manufacturing companies: When a component is missing, you also move from a standardized hierarchical organization to a situation in which you have to make flexible decisions. This is particularly important when it comes to last-minute changes – an employee calls in sick or a customer wants a specific part in red instead of blue just a few days before delivery. Through ambidextry – which essentially means »two right hands« – we want to achieve a smooth transition between standardized and flexible processes.

What does ambidextry mean for budatec?

Busse In a stable production environment, you have clear assignments and you know who is responsible for what. When unexpected circumstances arise, responsibilities and processes change. You can compare this to a journey you enter into your navigation system. If everything goes according to plan, the navigation system suggests the standard route. If there is a traffic jam or a road closure however, it determines possible alternative routes. In a similar way, ambidextrous software recognizes where problems occur and suggests solutions so that we can react in a good time.

Ihnen All of this can only succeed, though, if the employees are on the same page. That's why, with the company Accentus, we also have an organizational and personnel development consultant on board.

Funding notice

The project AmbiProd is funded by the German Federal Ministry of Education and Research (BMBF) in the »Future of value creation – research on production, service and work« (02J21C000) program and managed by the Project Management Agency Forschungszentrum Karlsruhe (PTKA). Funding code: 02J21C191

More information

www.ipk.fraunhofer.de/ambiprod-en

Contact

Deike Ihnen | +49 30 39006-284
deike.magret.ihnen@ipk.fraunhofer.de

A Safe Test Environment for Digital Production

Testing new technologies in operational production? Of course not! In the application laboratory »Digitally Integrated Production (dip)«, companies can test new technologies without jeopardizing their ongoing production.

What do we need a dip laboratory for?

Geisert Companies have to react more and more frequently to unforeseeable events, for example when supply chains are disrupted by armed conflicts. Digitalization can help here: It makes production more flexible, more resilient and therefore less susceptible to disruptions. We can demonstrate this in our dip laboratory, using examples of modular, flexible production processes for single-item and small-batch production. The twist: Instead of the conventional stand-alone solutions, we are offering a complete production scenario for the first time – from incoming order to finished product.

You are using the production of customizable fuel cells as an example application. Why fuel cells in particular?

Geisert We wanted a product that offers many variants in terms of performance and geometry – after all, customers in all sectors increasingly want items that are individually tailored to them. Additionally, the production of fuel cells involves tasks that are common to all manufacturing processes, such as milling, transport, labelling and assembly. Using the example of a fuel cell produced by our cooperation partner balticFuelCells GmbH, we can demonstrate how digitalization supports processes, and we can make it clearly understandable.

How do companies benefit from this?

Geisert Companies are often understandably reluctant to test new developments on live objects, i.e. during ongoing production. In the dip laboratory, we offer companies the necessary practice-oriented infrastructure in a protected environment – along with our scientific expertise. Suppliers, software providers and start-ups, on the other hand, benefit from production facilities for further development that they do not have. The dip laboratory does not stand still either – we will continue to develop it in line with the current needs of industry.

How far along are you with the construction of the dip laboratory?

Geisert We can already cover many aspects – it's great to see how various research projects can be linked to this unique laboratory and how this strengthens cross-institute collaboration. The central production systems of the process chain are already in place. However, as a living application laboratory, the dip laboratory will be continuously expanded with components that make digitally integrated production even more efficient.

Image

Project Manager Claudio Geisert explains how the dip application laboratory supports companies in testing new digital solutions.

More information

www.ipk.fraunhofer.de/dip-en

Contact

Claudio Geisert | +49 30 39006-133
claudio.geisert@ipk.fraunhofer.de

01

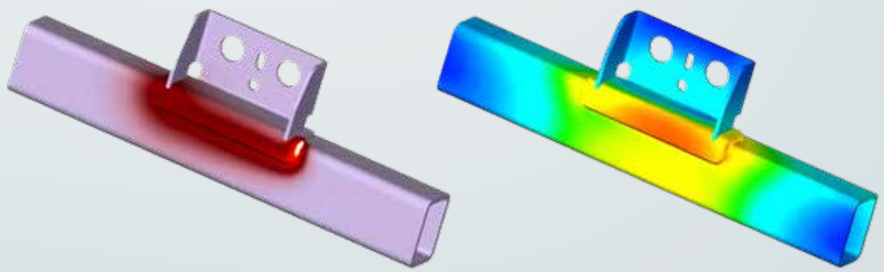
WELDING SIMULATION: TIME- AND COST-EFFICIENT PROCESSES

At Fraunhofer IPK, we use the latest simulation techniques to support companies in optimizing the quality of welded joints and significantly saving resources. By calculating welding distortion in advance with the help of simulations and precisely designing clamping fixtures, welded constructions can be optimized directly on a computer.

Virtual tests can be used to precisely evaluate designs and welding processes even before the first component exists in the real world. These innovative simulation methods replace cost-intensive pre-production tests.

A reduction in material and personnel costs of 30 to 70 percent offers our partners considerable advantages. Their production becomes more efficient and they become more competitive. With potential savings of up to 80 percent on prototypes, fixtures and designs, companies can make optimal use of their financial resources.

The virtual validation of welding processes, in addition to saving costs and time, also creates transparency regarding residual stresses and critical seams that can lead to distortion or failure. With our expertise, we can precisely predict and optimize not only individual joints but also complex welded assemblies, including the use of the latest manufacturing processes such as DED.



Contact
Vinzenz Müller
+49 30 39006-372
vinzenz.mueller@
ipk.fraunhofer.de

02

ENERGY MONITORING AND PROCESS OPTIMIZATION: ENERGY EFFICIENCY IN PRODUCTION

Due to rising energy costs, many SMEs as well as large companies are looking for solutions to save energy in their existing production processes without having to make significant investments. The TechEner project is therefore researching and developing technologies and tools for targeted, high-resolution, manufacturer- and machine-independent energy monitoring and making them available to industry.

Using the example of a production process chain implemented in an application laboratory, these methods and systems will be used to analyze the accruing energy flows at process chain, machine, machine component and process level. The technologies of drilling, milling, electrical discharge machining, laser ablation as well as injection moulding will be addressed and the energy data collected will be used for energy-specific process optimization. Subsequently, process chains, machine tools and their components are categorized in order to identify and cluster the main energy consumers. Based on these results, a methodical process optimization with a focus on reducing energy consumption for the various technologies is aimed for.

Funding notice
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Contact
Gero Esser
+49 30 39006-294
gero.maximilian.
esser@
ipk.fraunhofer.de

03

ROBOT SENSES: INCREASING PRECISION WITH HAPTICS

With the aim of freeing robots from their rigid operating areas in protective cells, we developed Tend-O-Bot. The advanced system integrates optical and haptic sensor feedback, enabling it to react flexibly to its environment – a milestone for tasks such as automated machine tending that were previously limited by their requirements.

The departure from purely visual data processing is groundbreaking. Instead, Tend-O-Bot uses data from force and torque sensors of its robotic arm to place objects with precision even where camera systems reach their limits. This is helpful when loading machines: The autonomous robot moves to the machine tool and visually determines its approximate position in front of the machine door. Instead of laboriously determining the required precision for the joining process optically, it relies on its tactile sensitivity for tending. This saves time and enables robust interaction with the machine tool.

In addition to its enhanced sensory capabilities, Tend-O-Bot has also been brought up to date in terms of its network technology. Equipped with WiFi 6, it can execute even power-hungry AI algorithms quickly and easily in the cloud. Computing in the cloud saves valuable energy on board the vehicle and reduces the frequency of charging breaks. This means Tend-O-Bot is always ready for new tasks.

Contact
Sönke Niemann
+49 30 39006-291
soenke.niemann@
ipk.fraunhofer.de

Intelligent Mechatronic Systems Technology

Machines – The Heart of the Factory

Every manufacturing process hinges on them, and as such they are a crucial starting point for optimizations of all kinds: Machine tools, robots and other systems are constantly reaching new levels of efficiency through digital upgrades or process adaptations.

Whether energy- and resource-efficient turning, milling and grinding in large machining centers, assembly with perceptive robots, manufacturing of new types of geometries or processing of innovative materials in entirely new processes: There is a lot of research potential in machine and system technology on the shop floor. In the age of digital networking, equipping systems with innovative sensor technology and using it for control and monitoring is the first obvious step. But that is just the tip of the iceberg.

At Fraunhofer IPK, systems technology is viewed from a wide variety of perspectives. The adaptation of machining strategies generates solutions for practical challenges in terms of surface quality or energy efficiency. At the same time, they make new materials machinable in the first place, for instance those required in the automotive sector. Where existing processes reach their limits, we create new ones: add-ons for established systems technology, solutions for the additive manufacturing of complex geometries or fundamentally new machine technology, for example for medical and pharmaceutical applications.

Of course, digitalization at the machine level does not get overlooked at Fraunhofer IPK either. We make systems capable of communicating, using sensors and network technology to allow them to report their status or interact with a higher-level control system. And we enable robots to independently perceive and adapt to their environment based on visual, haptic and acoustic input.

Machining, but Make It Better

Machining is a core expertise at Fraunhofer IPK – and a down-to-earth field. Companies receive support with immediate practical relevance.

As a key area of manufacturing science, machining is firmly anchored at Fraunhofer IPK – from macro to micro scale. It is not a discipline that produces groundbreaking innovations, but: »We support our customers with the hands-on challenges they are facing,« reports Ingmar Thiede, one of the institute's machining experts. Inquiries from companies often concern processes that are generally working but are supposed to be more productive or economical.

The questions and issues are diverse. Often factors such as processing times or tool costs should be reduced while maintaining the same surface quality and dimensional accuracy. Or we receive requests for machining strategies with the appropriate tolerances for new products and materials, or our objective is to reduce the need for post-processing.

Solutions range from determining more suitable cutting parameters or adapting tool path strategies to tool optimization. »We always look at the overall process,« reports Thiede. »After all, what is the benefit of optimizing the process time during machining, but creating excessive burrs that require more post-processing?«

»The right milling strategy is particularly relevant for components that place extreme demands on the machined structures and surfaces in terms of planar parallelism or roughness,« says Muzaffer Dargin, who deals with ultra-precision machining. There is also a lot to consider when it comes to ultra-precision machining of complex components. When there are sharp directional changes during tool engagement, for example, the tool may stand still on the surface briefly, creating unsightly marks. »We optimize milling strategies so that these changes in direction become unnecessary or more continuous, thereby reducing their impact,« summarizes Thiede.

Certain materials offer potential for optimization as well – very hard materials, for example, result in longer process times and greater wear on tools. »We are improving tool properties and developing new cutting materials in response«, says Dargin. Milling tools made of diamond or cemented carbide, for example, are harder thanks to their composition and show fewer wear marks than conventional milling tools.

There are some areas in machining where real innovations are taking place – most of them separate from the actual cutting process. One example is automated CAM planning for the machining of used parts. Another is increasing energy efficiency by identifying consumers that can be avoided by adapting the milling strategy. And even seemingly exotic topics such as robotic milling are addressed at the institute.

Images

Face milling of Inconel using ceramic inserts to determine the optimum machining parameters (left)

The hardness of milling tools is increased by reducing the cobalt content (right)

More information

www.ipk.fraunhofer.de/production-processes

www.ipk.fraunhofer.de/precision-manufacturing

Contact

Muzaffer Dargin
+49 30 39006-323
muzaffer.dargin@ipk.fraunhofer.de

Ingmar Thiede
+49 30 39006-246
ingmar.thiede@ipk.fraunhofer.de

Better, Faster: Production

Agile, fit for circularity and digitally supported – these are the requirements for modern production. To meet them, manufacturers must put a spotlight on their technologies, machines and systems.

One of the ways our researchers are getting production ready for the circular economy is by developing process and tool technologies for dry machining. By not requiring liquid dielectrics and coolants or peripheral equipment, they make it possible to avoid environmentally harmful waste, as well as saving resources and energy. Dry and residue-free machining using CO_2 shot peening, for example, is of interest for large and complex lightweight components in the wind energy, aviation and automotive industries. For this purpose, a new system is being developed at Fraunhofer IPK that is designed to increase productivity by up to 25 percent and reduce processing costs by up to 60 percent compared to conventional systems. In terms of cleaning processes, wet-chemical processes have been replaced by CO_2 technologies for some time now. CO_2 snow blasting technology is being developed further for cleaning bipolar plates for fuel cells and electrolyzers. Prof. Julian Polte, head of the Production Systems division at Fraunhofer IPK, is convinced that »if manufacturers succeed in making their production processes more energy- and resource-efficient, they will automatically increase their productivity and reliability as well.«

Image
FDmix-M mixer for producing nanoparticles

Focus on machine tools
Machine tools themselves offer many potential starting points for making the machining of complex components economical and reliable. For example, our researchers are investigating how wear during milling can be reduced with the help of clamping device optimization. To simulate natural frequencies in machining, they have developed an alternative workpiece clamping concept with better workpiece accessibility. The new system aims to significantly reduce tool wear while simultaneously allowing for an increased feed rate. Another new feature is an automated external flushing unit for die-sinking EDM machines, which ensures reproducible machining results and up to 30 percent faster machining.

Solutions for tool-free production, which can be used to overcome supply bottlenecks and reduce development times (for example for new electric drives), are also part of current research and development projects, as is the integration of mobile robot platforms and lightweight industrial robots into logistics. In the future this could enable SMEs to connect machine tools and assembly stations to each other quickly and flexibly, thereby reducing set-up times by up to 50 percent. From a technological perspective, additive manufacturing makes possible what can no longer be produced conventionally: complex structures generated with the help of AI for high-performance tools that can deliver a very high cooling capacity close to the contour, or for heat exchangers, which are an important part of the thermal management in electric vehicles.

Highest precision in the name of health
The medical and life sciences sectors can benefit from new technologies as well, for example in the production of mRNA-based medications. Many production processes in the pharmaceutical industry are based on technical mixing processes. The mixing quality not only determines the quality of products such as active ingredients in medications and nanoparticles, but ultimately also their effectiveness. The FDmix platform, a joint development between Fraunhofer IPK and FDX Fluid Dynamix GmbH, achieves mixtures of unprecedented homogeneity with minimal mixing times and is scalable across a wide volume flow range. The platform enables efficient and robust series production of pharmaceutical and chemical industry products. »FDmix is an outstanding example of how we create technological solutions that ultimately benefit every single patient,« says Dr. Christoph Hein, head of the Ultra- and High-Precision Technology division.

This also includes the latest in-vitro methods, microproduction technologies and imaging processes to improve the surfaces of implants and avoid clinical complications after dental, hip or knee surgeries. Active substances can be tested safely, without the need for animal testing, using organ-on-a-chip technologies that our researchers are working on. And a new inline CT system checks medical polymer parts such as heart valves 50 times faster than conventional measuring methods thanks to AI-supported data evaluation – thus enabling a 100 percent control in the production cycle for the first time.

»If manufacturers succeed in making their production processes more energy- and resource-efficient, they will automatically increase their productivity and reliability as well.«

More Information

www.ipk.fraunhofer.de/cold-spray-en

www.ipk.fraunhofer.de/mrna-en

www.ipk.fraunhofer.de/fdmix-en

www.ipk.fraunhofer.de/mobilab-4d-en

Contact

Dr.-Ing. Christoph Hein
+49 30 39006-405
christoph.hein@ipk.fraunhofer.de

Prof. Dr.-Ing. Julian Polte
+49 30 39006-433
julian.polte@ipk.fraunhofer.de

Additive Beats Conventional

Tobias Neuwald, head of the Manufacturing Technologies department, and Dr. Max Biegler, head of the Joining and Coating Technology department, are experts in metal additive manufacturing.

Image
With their expertise in powder bed fusion (PBF-LB/M) and directed energy deposition (DED), the teams of Dr. Max Biegler and Tobias Neuwald complement each other perfectly.

What is the focus of your research right now?
Neuwald We are researching the use of powder bed technologies along the entire additive value chain. Here we investigate questions such as: Where are the limits when processing materials that are difficult to weld? What will the production systems of the future look like? What needs to be done to the components after printing? And how can I avoid having to do a 100 percent CT-inspection in safety-critical applications such as aviation, medical technology or the energy sector?

Biegler We stay close to the process: How do I apply certain materials? How do I design the process to robustly achieve high quality results? We mainly investigate these questions for DED processes. We also support companies in the selection of use cases: Where is using additive manufacturing technologies economical?

And where is that the case?
Biegler When repairing very large and expensive tools in car body manufacturing or forging operations. In these cases, existing damaged areas are removed and then manually restored by a welder. We have automated these manual steps. When additive technologies become cheaper, they will also become interesting for the repair of components that only cost 1,000 and not 20,000 euros.

Neuwald Burner heads for energy production are already being manufactured additively today. The advantage here is that I can consolidate the production of individual components and their assembly and adjustment into a single part and create more complex geometries that improve the combustion. This approach adds value that the chemical and process industry will also benefit from in the coming years.

Why are simulations important?
Biegler Because the processes are so complicated. Trial and error is too costly here. With simulation processes, we can explore our parameter window without taking up any machine hours and perhaps achieve First Time Right directly.

Neuwald Additionally, components deform during the process. That is why we are working on simulation tools that also offer a reliable distortion simulation so that we can properly compensate the components in advance.

More information
www.ipk.fraunhofer.de/additive-manufacturing

Contact
Dr.-Ing. Max Biegler | +49 30 39006-404
max.biegler@ipk.fraunhofer.de
Tobias Neuwald | +49 30 39006-308
tobias.neuwald@ipk.fraunhofer.de

Robot Cognition: See, Hear, Feel, Do

The use of sensors and AI are expanding the application areas of robots beyond just industry. Our team develops innovative automation approaches and evaluates where they can be economically viable.

Technological progress makes automation conceivable in areas that go far beyond the current field of application for robotics. Imagine robots making your hotel bed, harvesting cucumbers or stocking shelves in the supermarket. What all of these scenarios have in common is that they involve tasks that cannot be programmed down to the millimeter, because the manipulated objects are not in a fixed known position. Experts refer to such tasks as automation in partially or even unstructured environments.

In order for robots to master such tasks, a certain form of intelligence is required: The machine must be able to perceive its surroundings, make decisions, and plan freely. »The aim is to simply be able to say: ›Grasp the object in a secure way and move it to B‹,« says Dr. Gregor Thiele, head of the Process Automation and Robotics department. What sounds trivial is actually a highly complex field of work that brings together cognitive robotics and advanced actuator technology.

Cognitive robotics allows robots to perceive and understand their surroundings. Image sensor technology enables the identification of workpieces, targets and obstacles. Force sensors are an important addition, as tactile feeling optimally complements visual perception. Acoustic signals can also be relevant, for example to evaluate the sound of objects locking into place. »The processing of signals like these has made huge leaps forward in recent years thanks to advances in machine learning and AI,« says Oliver Heimann, head of the Machine Vision department.

However, there is still a lot of work to be done when it comes to making the transmitted signals usable: Combining them into an overall understanding and making the right decisions is time-consuming; deriving actions that meet the requirements of the application in terms of speed and robustness even more so. And, »if a process looks slightly different each time, it gets more difficult to assess whether it is running correctly,« summarizes Thiele.

All of this currently makes it difficult for users to commit to automation. »This is where our automation assessment provides support,« explains Arturo Bastidas-Cruz, who developed the method. »We use a systematic approach to assess which processes could be considered for automation.« The assessment does not just deliver a hard ›yes‹ or ›no‹ as to whether automation makes technical and economic sense. It can also end up recommending to automate sub-processes, to attempt a human-robot collaboration or to set up entire processes differently so that robots can manage them more easily.

Heimann and Thiele's teams also go beyond recommendations: Their departments of around 60 in-house experts build prototypical implementations to show that a solution is feasible. They combine suitable hardware with the appropriate signal processing solution, thus minimizing the decision-making risk for companies that use automation solutions as well as integrators who want to implement them.

More information
www.ipk.fraunhofer.de/automation
www.ipk.fraunhofer.de/automation-assessment-en

Contact
Arturo Bastidas-Cruz
+49 30 39006-142
arturo.bastidas-cruz@ipk.fraunhofer.de
Oliver Heimann
+49 30 39006-327
oliver.heimann@ipk.fraunhofer.de
Dr.-Ing. Gregor Thiele
+49 30 39006-394
gregor.thiele@ipk.fraunhofer.de

01

SMARTOOL: QUALITY ASSURANCE THROUGH AUTONOMOUS SENSOR SYSTEMS

A central challenge of manufacturing control and production quality in injection molding and punching is the transparency of process parameters. Manufacturers of injection molds often do not know how they will be used, as they are operated by external service providers. In order to optimize quality and efficiency, it is important to link part quality to production conditions. Incorrect setting of the process variables can lead to defects in the product and high reject rates.

The SmarTool (Development of an innovative measuring system in stamping and injection molding tools to increase manufacturing control and production quality) project is developing autonomous sensor systems that monitor stamping and injection molding processes. They use external components to record and document important production data such as time and location of the tool usage, the number of units produced and the most important processing parameters.

Partners:
- FQS Forschungsgemeinschaft e. V. (FQS Research Association)
- SENAI Innovation Institute for Manufacturing Systems
- SENAI Innovation Institutes for Embedded Systems
- Eleven Brazilian and five German companies from the automotive, tool and die, and medical technology sectors

Funding notice

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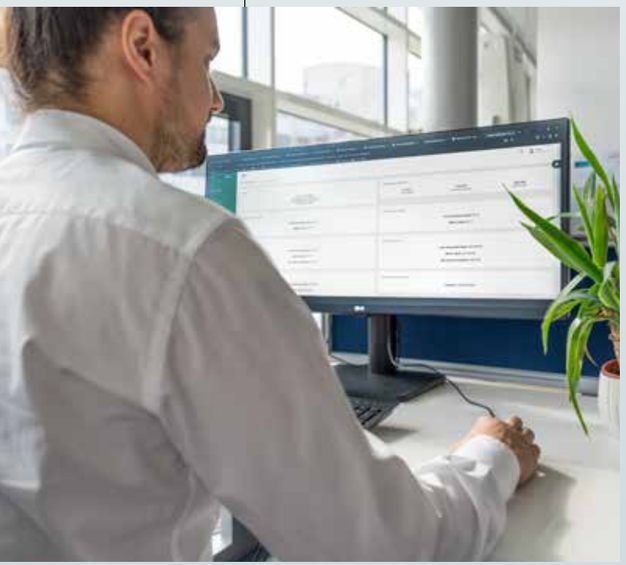
Contact

Robert Bolz
+49 30 39006-390
robert.bolz@
ipk.fraunhofer.de



02

OPTIMIZING RESISTANCE SPOT WELDING WITH THE HELP OF AI

The automotive industry promotes lightweight construction and safety by using high-strength steel sheets that are joined using resistance spot welding (RSW). However, spatter that can occur during welding affects the quality of the spot welds and poses a safety risk. In order to ensure stability in spite of this, manufacturers often opt for making more spot welds than would be necessary.

To avoid spatter formation during RSW, we have developed a methodical approach based on multi-parametric process analysis and AI. A comprehensive analysis of the data generated during the welding process enables the AI to precisely predict the occurrence of spatter. If necessary, the current is switched off briefly to prevent spatter. This intelligent control makes the welding spots larger and the joints more stable. Our research combines practical experiments and computer simulation to train the behavior of the AI and investigate the effects of spatter on the stability of the end product.

The use of AI in resistance spot welding ensures safer and higher quality sheet metal processing. This innovation promises significant progress for smaller sheet metal processing businesses in particular – because the optimized handling of modern materials can significantly increase their competitiveness.

Funding notice

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Contact

Bassel El-Sari
+49 30 39006-295
bassel.el-sari@
ipk.fraunhofer.de

03

ROBOTIC SKILLS: WIRING ASSEMBLY FOR ELECTRIC MOBILITY

The transition to electric mobility presents a new challenge for the automotive industry: It is necessary to route a large number of cables and electrical components efficiently. This task requires careful handling of many flexible elements. Laying cables and assembling plug connections manually is time-consuming and cost-intensive.

Fraunhofer IPK is developing solutions in the field of robotic automation that address this challenge. A key component is the use of force sensors and cameras. Alongside an intelligent control system, they make it possible to imitate how humans »feel« and »see« the cables during the handling and assembly process. This enables the robots to react to deviations and unpredictable behavior of the components immediately and continuously – an important prerequisite for the automation of such tasks. Recorded images and force signals enable quality assurance in real time, including detection of deviations, before the product can be damaged.

Robot-assisted assembly thus reduces repetitive, time-consuming and potentially unergonomic activities. The safety and reliability of the processes are the primary focus. We collaborate with industry partners in analyzing manual processes, assessing the technical feasibility of automation in our specialized laboratories and supporting integration into production.

Contact

Kevin Haninger
+49 30 39006-139
kevin.haninger@
ipk.fraunhofer.de

Knowledge and Assistance in Production

Support for the Human Resource

Qualified staff is the key to company success – nothing works in production without committed employees. However, in view of the shortage of skilled workers, it is difficult to find optimally trained personnel, making it all the more important to provide employees with the best possible training and support.

Work on the shop floor today is more demanding than ever before. Machines are becoming more complex to operate, optimally configuring processes is becoming more difficult – at the same time, quality demands on the production result are increasing. Even highly qualified and experienced specialists are finding it increasingly difficult to run processes optimally. But in many cases, such machine operators are now in short supply – manufacturing companies often rely on lateral entrants or temporary workers who lack the specific know-how for the existing systems.

In order to ensure the best possible production under such conditions, Fraunhofer IPK is pursuing a two-pronged approach. On one side, we are developing context-based assistance systems that meet manufacturing employees exactly where they stand. They provide process or machine knowledge as needed and support the execution of set-up or maintenance work, in several languages if necessary. At the same time, we make sure that support is designed in such a way that employees neither feel disempowered nor helplessly at the mercy of the process.

On the other hand, we support companies in training their staff for new tasks in the best possible way. No assistance system in the world will replace people's decision-making skills in the near future, especially in extraordinary situations. This is why we develop educational games and environments that introduce employees to new methods as well as AI-based tools that support companies in identifying suitable continuing education programs.

Continuous Information Flow Within Companies

When information is in the wrong place, it is essentially worthless. Kathrin Konkol and Erik Paul Konietzko explain how semantic data structures serve to optimize the data flow within companies.

Image

Are we talking about the same thing? Semantic data structures and extended reality help experts from different domains to agree on solutions without misunderstandings.

More information

www.ipk.fraunhofer.de/semantic-data-integration

<u>One would assume that information is available in abundance. Where is the challenge?</u>

Konietzko Although most employees in a company speak the same language, there is still a kind of Babylonian language labyrinth between departments: The designers use different names for components than the assembly workers. Each department also has its own software, which leads to imbalances in the flow of information.

Konkol And through good visual depiction, complex issues can become easier to comprehend. This is where suitable visualizations help to relieve the cognitive burden on experts. They make complex structures tangible without simplifying the contained information or losing artifacts of the development. This way, misunderstandings can be identified and corrected at a very early stage. And it also becomes clear whether the chosen semantics are actually effective.

<u>Semantic data structures form the basis of your solution. What are those?</u>

Konietzko One example: In the project Cockpit 4.0 which we carried out with Rolls-Royce – involving the production of turbines – we linked information from the design stage with that from the assembly. Which problems occurring in assembly can be traced back to missing information from the design? And how can we feed findings about this back to the design team? We have created an ontology to illustrate these connections. You can think of it like a mind map. The nodes represent the information, the edges show the relationships between the nodes. This is what we call semantic data structures.

<u>What are the resulting benefits for Rolls-Royce?</u>

Konietzko In manufacturing, the more information and insight is available, the better the decisions that are made – whether in terms of production costs and times or of the quality that is achieved. But it is a utopian idea to standardize the software systems between design and assembly – after all, the entire production process depends on them. Nevertheless, companies such as Rolls-Royce can use semantic structures to exchange information between the systems and increase the efficiency of the production process. Take this example: Certain dimensions of a component are incorrect, so it is considered a reject. Assembly workers feed this information into the semantic system, the design team receives it and can resolve the problem in the future.

<u>Fraunhofer IPK has also developed an extended reality demonstrator. What is that?</u>

Konkol Using VR glasses, the assembly workers can view the information flow in 3D space – without having to use a PC. This means everything is in their field of view and their hands are free for the assembly. Additional assembly assistance is also possible: It shows which part needs to be assembled and how.

Contact

Erik Paul Konietzko | +49 30 39006-387
erik.paul.konietzko@ipk.fraunhofer.de

Kathrin Konkol | +49 30 39006-382
kathrin.konkol@ipk.fraunhofer.de

Machine Operation App-Solutely Under Control

Machines and production systems are becoming more and more complex. App-based assistance systems aim to support employees with maintenance and overhaul.

Machine operation has become a complex challenge for many companies. On the one hand, they are facing a workforce problem: Experienced specialists are often no longer able to properly transfer their extensive knowledge to a sufficient number of junior staff. Instead, more and more lateral entrants are arriving on the shop floor and have to be trained at short notice. At the same time, operating the systems and machines is becoming more and more complicated, even for experienced employees. This is not only because the machines have more and more features, but also because the requirements for efficiency and workpiece quality are increasing.

Assistance systems can help to defuse this situation: Mobile applications on smartphones or tablets support the training phase and process control. They can be used to provide information on the machine, component or production process in a simplified and situational way.

App-supported process setup
When it comes to guiding the setup process on a milling machine, for example, the correct machine is first identified using a serial number or a QR code. The application then guides the user through the individual tasks step by step: loosening the milling head, chucking the tool, tightening the milling head again. Which tool or stock material is required for each step is displayed on the smartphone screen. Pictures or videos illustrate the explanations, if necessary with translations into various languages.

But that is not all: Sophisticated sensors within the machines check whether all steps have been carried out correctly. For example, the chuck has sensors that check whether the workpiece has been tightened with the correct clamping force. This means that even beginners can quickly carry out the correct operations. Intelligent sensor technology can also support the determination of optimal process parameters – saving energy and material and achieving machining results of the highest quality.

In-situ monitoring saves time and cost
Even while a process is running, sensors in the systems continuously monitor various parameters such as pressures, temperatures and energy consumption. »Deviations from the ideal parameters indicate that something is going wrong in the process,« explains Philipp Lelidis, research scientist in the Production Machines and System Management department. Such indicators also point to where the problem lies.

One use case is additive manufacturing, for example in metal 3D printing, which is mainly used in the aerospace and medical industries. Such processes often take several hours. If the employees only realize afterwards that there has been an error and the component is unusable, time and raw materials have been wasted.

»We are researching how the machine can use sensors to automatically detect where the problem may be, what impact this has on the component and what countermeasures we can take to still end up with a perfect component,« says Lelidis. This in-situ monitoring can also reduce the extent of required quality assurance in the end.

»We are researching how the machine can use sensors to automatically detect where the problem may be.«

AI for pattern recognition and process optimization
Another example of the benefits of in-situ monitoring is laser machining. »A laser beam can cut, drill or remove fine layers from the surface of the material,« explains Luiz Guilherme De Souza Schweitzer, who leads the Process Technologies department in the Ultra- and High-Precision Technology division. Particularly precise work is carried out using laser pulses that are only a few femtoseconds long. When they hit a material, it sublimates – i.e. it changes from the solid to the gaseous state. The acoustic spectrum of this vapor can be measured using optical microphones.

There is an ideal acoustic spectrum for every process. Deviations from it indicate that errors have occurred. At present, it is still very difficult to read out these acoustic spectrums. Schweitzer is therefore working on training an artificial intelligence to recognize faulty patterns and carry out optimization procedures on the process. »We only have this expertise in-house at the moment, but testing with customers is already underway,« explains Schweitzer.

Werk 4.0 increases resilience in production
What works on a small scale now should also function on a large scale in the future. As part of the Werk 4.0 project (see p. 14), Fraunhofer IPK is working on equipping not just individual systems, but an entire plant with digital assistance systems. This should also reduce the workload for employees as well as help to make manufacturing jobs more accessible and fill them despite the shortage of skilled workers.

More information

www.ipk.fraunhofer.de/assistance-systems

www.ipk.fraunhofer.de/in-situ-monitoring-laser-machining

Contact

Philipp Lelidis
+49 30 39006-453
philipp.lelidis@ipk.fraunhofer.de

Dr.-Ing. Luiz Guilherme De Souza Schweitzer
+49 30 39006-411
luiz.schweitzer@ipk.fraunhofer.de

Gaming? Let's Get Serious!

What we experience ourselves is more likely to be recognized in the future. Researchers at Fraunhofer IPK are taking advantage of this with serious games.

When children are deeply immersed in a game, they not only have fun, they often learn something as well. After all, associations and connections are best remembered when we are not just told about them, but experience them for ourselves. What applies to children also applies to adults. This is why researchers at Fraunhofer IPK let company employees play – with building bricks. »This allows employees to quickly see themselves in the reality of even complex manufacturing companies,« explains Jens Mathis Rieckmann, a researcher in the Corporate Management division.

Anchoring knowledge haptically

The bricks are used to simulate a drilling machine factory. The drilling machine serves as an example to allow participants to experience interconnected production processes haptically and experiment with them. »Initially, the main focus was on streamlining the processes: The participants take on a traditional production process, which they streamline and optimize step by step,« says Natalie Petrusch, who is working on the serious games together with Rieckmann. »Today, ›LearnFactory 5.0‹ is all about digital networking and people at the heart of the production process of tomorrow. The ›Competitive Sustainable Manufacturing‹ project (see p. 51), on the other hand, focuses on sustainable value creation: What to do if a supplier loses its certification? The customer's wishes determine the duration, difficulty and focus.«

Rapid development with serious games

Gamified solutions developed by Fraunhofer IPK not only support learning, but also enable rapid and surprisingly cost-effective development processes. The introduction of digital product passports for batteries is a prime example. The team succeeded in implementing digitally supported circular processes within just one month with less than 75 euros in material costs.

Hands-on learning with LearnFactory kits

While the building brick game is primarily aimed at better anchoring general knowledge about production processes, »Kits for LearnFactories« focus on the hands-on training of self-contained subjects, for example finding and correcting errors. »Our new kit on total productive maintenance (TPM) consists of a demonstrator with numerous defective as well as some correct screw connections, instructions on its setup and function, as well as a course with a guide for trainers,« explains Petrusch. With the help of this kit, employees at any location worldwide can be trained to the same standard.

Image

An example of a serious game: LearnFactory 5.0 enables gamified learning and optimization of business processes.

More information

www.ipk.fraunhofer.de/qualification

Contact

Natalie Petrusch
+49 30 39006-310
natalie.petrusch@ipk.fraunhofer.de

Jens Mathis Rieckmann
+49 30 39006-376
jens.mathis.rieckmann@ipk.fraunhofer.de

AI-Improved Learning

SMEs often struggle when it comes to their employees' skill development. The KIRA Pro project is developing a tool for selecting training learning content and exercises.

Image

Maria Kretschmer (left) and Katrin Singer-Coudoux (right) are developing an AI-supported continuing education compass based on automatically generated learning paths.

<u>KIRA Pro is primarily aimed at SMEs. What are their challenges?</u>

Singer-Coudoux In Germany, we are increasingly faced with the problem of a shortage of skilled workers: The wave of automation brought about by Industry 4.0 is changing the requirements for employees' skills and abilities. After all, the digital transformation is also having an impact on job profiles: Instead of mechatronics engineers, for example, machine operators with programming skills could be needed. Further occupational training is therefore essential for the future viability of companies. However, while many large companies systematically train their staff, SMEs often lack the capacity to do so.

<u>How can KIRA Pro help?</u>

Kretschmer The project takes two approaches. Firstly, we are developing a learning platform that SMEs can use to train their employees cost-effectively. Here we are also taking into account the fact that the way of learning is changing – instead of sending someone to a training course, people now tend to use micro-learning units and new learning formats such as podcasts. But which ones? After all, there is a jungle of offerings out there. With the help of the learning platform, we are trying to make that manageable for SMEs. The second approach is to continuously update employees' job profiles. This way, we can develop targeted skills (e.g. digitalization skills) that make companies more resilient, even in times of crisis.

<u>What does that mean for companies?</u>

Singer-Coudoux We are bringing together the strategic level of the company – i.e. questions around the direction of development – with the operational level, i.e. the training of individual employees. What skills do employees need, for example, when a new product is being launched? We are developing a learning path generator that uses AI to compare employees' actual skills with the targeted ones and creates a learning path with a tailored selection of learning content. The system brings together four points: the company's requirements, the employees' personal development goals, their individual skill level and the available range of training options.

Kretschmer A point that I find particularly fascinating and that is becoming increasingly important, especially in challenging times when people feel left behind, is this: KIRA Pro can help to strengthen participation – to which, after all, education and continued training is a key element. By empowering people to work in new professions, we are enabling participation and stabilizing the democratic society.

Funding Notice

The research and development project KIRA Pro was funded by the German Federal Ministry of Education and Research (BMBF) in the INVITE (Digital Platform for Continuing Vocational Education and Training) innovation competition and supervised by the Federal Institute for Vocational Education and Training (BIBB).

More information

www.ipk.fraunhofer.de/kira-pro-en

Contact

Maria Kretschmer | +49 30 39006-264
maria.kretschmer@ipk.fraunhofer.de

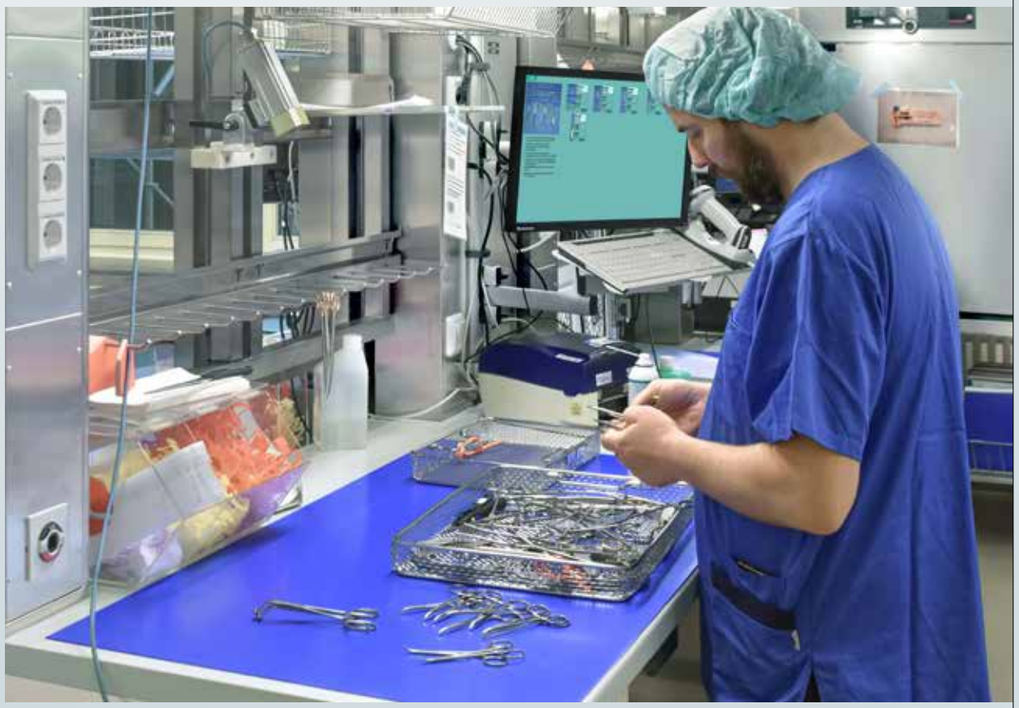
Katrin Singer-Coudoux | +49 30 39006-371
katrin.singer@ipk.fraunhofer.de

01

CIR.LOG®: A RETROFITTABLE AI CAMERA FOR STERILE GOODS LOGISTICS IN HOSPITALS

Complaints about missing instruments in the operating theater are part of everyday life in hospitals. An AI-supported system to automatically check whether all instruments are in place is supposed to prevent such incidents in the future. Cir.Log® introduces the latest AI technology to sterile goods logistics: An intelligent camera optimizes the reconditioning process for medical devices. It identifies and counts surgical instruments automatically and without the need for additional identification such as RFID chips. This not only significantly reduces the workload for hospital employees, but also ensures seamless documentation – from cleaning facilities to operating tables.

Automatic detection ensures that each individual instrument is correctly sorted for surgery. The camera works like a barcode scanner, only without any barcodes. Photos document the packaging process seamlessly and automatically, which increases safety and efficiency and drastically reduces errors. Overall, Cir.Log® promises to fundamentally improve workflows in the reconditioning of medical equipment – for more productivity, lower costs and greater patient safety. Complex challenges such as the shortage of skilled workers can in turn be managed more successfully, making jobs in this particular field become more attractive.



Funding notice

The European Union, together with the German Federal Ministry for Economic Affairs and Climate Action, supports the program »Existenzgründungen aus der Wissenschaft (EXIST)« (»University-Based Business Start-Ups«) in Germany via the European Social Fund Plus (ESF Plus). Funding reference 03EFWBE151

Contact

Ole Kröger
+49 30 39006-464
ole.kroeger@
ipk.fraunhofer.de

02

MORE TRANSPARENCY IN MAINTENANCE WITH SMART DEVICES AND DIGITAL TWINS

When it comes to production support and maintenance of machines and systems, it is particularly important to document the completed steps transparently so that other employees can determine which operations have been carried out. Fraunhofer IPK has developed a mobile maintenance support system that addresses this issue with the help of smart devices.

This involves creating a digital twin of a production system that provides information about the machines' status in real time, acting as a virtual representation of the machines. The intuitive design of the human-machine interaction, for example with touch screens or voice control, allows even less experienced employees to operate the systems. Operating instructions can be adapted to the user's abilities. Even complex tasks can be more easily managed and new employees can be trained more quickly. Documenting work transparently contributes significantly to increasing efficiency by making processes traceable and optimizable. By improving communication, reducing downtimes and ensuring the transfer of knowledge, transparent documentation enables a higher level of operational control.

Contact

Claudio Geisert
+49 30 39006-133
claudio.geisert@
ipk.fraunhofer.de

03

EFFICIENCY AND PRECISION: COMBINED PROCESSES FOR HOUSING PRODUCTION IN ELECTRIC MOBILITY

Housings for electric motors and batteries are extremely challenging components. They have to be stable and heat-resistant, fit precisely and be as light as possible. Until now, many individual parts have to be laboriously screwed together.

Welding processes offer clear advantages over screw connections: They are more efficient, more flexible and particularly suitable for producing electric motor and battery housings. Fraunhofer IPK combines traditional continuous casting with wire arc additive manufacturing (WAAM), a process that simplifies production while maintaining nearly identical component strength, shortening assembly times and minimizing the number of components.

Although aluminum is a lightweight material well suited for casting, it also creates challenges such as pore formation or adhesion defects during welding. Fraunhofer IPK is tackling these problems with an intelligent monitoring system that uses AI and sensors to ensure precise 3D printing. Similar to an intelligent co-pilot in a car, this technology protects the manufacturing process from errors and ensures the production of optimal components – an exemplary combination of high-end technology and engineering expertise.

Funding notice

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Contact

Benedikt Neumann
+49 30 39006-247
benedikt.bog.man.
neumann@
ipk.fraunhofer.de

Sustainability and Environmental Compatibility

Towards a Green Production

Manufacturing companies carry great responsibility. Those who use resources and energy on a large scale to produce what must one day be disposed of in an environmentally friendly way would do well to design processes and products sustainably – for ethical as well as economic reasons.

Sustainability has many aspects. Using resources sparingly not only protects the company's bottom line. Businesses that operate with less energy and other raw materials in their production benefit financially and at the same time make an important contribution to securing the future of our planet. If this alone is not a strong enough incentive, legal regulations require companies to reduce greenhouse gas emissions or make products traceable.

The starting points for sustainable product and production design are found very early in the product life cycle. Companies can maximize their impact if they consider how and from where raw materials and semi-finished products are procured or under what conditions a product will be manufactured already during product development. At Fraunhofer IPK, we research methods, tools, technologies and materials in order to design products sustainably throughout their entire life cycle – all the way to true circularity.

In this context, we are particularly concerned with increasing the international competitiveness of Germany as a production location. High energy costs, strict CO_2 regulations and other regulatory requirements confront companies in Germany and Europe with major challenges. We enable companies to implement regulations, not least to ensure the greatest possible transparency for customers and partners. And we create solutions to future-proof established industries during transformation processes – a good example is the automotive sector.

Images

micro resist technology GmbH develops, produces and distributes innovative photoresists, polymers, photopolymers and ancillaries for micro- and nanostructuring processes. Dr. Sylvia Herrndorf is responsible for quality, environmental and project management, Dr. Thomas Wiglenda is a chemist in R&D and supports the preparation of a greenhouse gas balance for the company.

Dr. Ronald Orth heads the Business Excellence Methods department at Fraunhofer IPK. With the KliMaWirtschaft project, his team aims to support SMEs in particular with climate management.

Our Goal: Smaller Footprints

How can SMEs systematically set up climate management? The KliMaWirtschaft project provides answers. The company micro resist technology GmbH has tried out the solutions.

What is the aim of the KliMaWirtschaft project?

Orth The project aims to guide small and medium-sized enterprises from a basic understanding of »how to tackle climate protection« to the definition and implementation of concrete measures. To do so, workshops and instructions are offered that meet the companies where they currently stand. The offer is free of charge and around 300 companies have taken advantage of it so far.

Herrndorf And that is very good! SMEs make up the largest part of the German economic strength and should – in our view – also have the greatest overall impact on climate protection.

What motivated micro resist to join the project?

Herrndorf Our customers increasingly ask about the greenhouse gas (GHG) emissions of individual products. We were previously unable to answer these questions because we did not know the figures ourselves. We have had a certified environmental management system since 2011, but quantifying emissions is a separate issue.

Wiglenda We have the chemical expertise to determine the GHG emissions of our products, but we lacked the methodological skills. That begins with the question of the right scale: Do we look at the entire company, the business units or does the individual product provide us with most of the information? And in the last case, where do we get reliable figures for the raw materials?

And this is where KliMaWirtschaft creates the necessary access?

Orth Exactly. We start with workshops and regional group meetings that explain how to get started with climate accounting. To do this, we introduce the companies to tools that they can then use to calculate their GHG footprint. Based on this, further workshops are held to select measures for improvement that result in a comprehensive climate protection strategy. We are developing a toolbox with solutions for this.

Herrndorf This systematic approach is what makes the project so interesting for us. As with many companies, time is the limiting factor for us. The structured instructions help us to pursue the topic as efficiently as possible.

Wiglenda I am particularly impressed by how well the content is prepared. You are provided with the necessary knowledge in a very compact form and save yourself a lot of research. This makes it much quicker to get started. We are now in the process of compiling our GHG balance and are already very excited about the development of the strategy in the follow-up workshop.

Funding notice

The KliMaWirtschaft project is funded by the German Federal Ministry of Economics and Climate Protection (BMWK) as part of the funding call for innovative climate protection projects of the National Climate Initiative (NKI). Funding code: 67KF0166A.

More information

www.ipk.fraunhofer.de/klimawirtschaft-en

Contact

Dr.-Ing. Ronald Orth | +49 30 39006-171
ronald.orth@ipk.fraunhofer.de


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Sustainability Into Industry

Climate-neutral, resource-saving, eco-friendly: The requirements that products and their manufacturing must meet are changing dramatically. Companies need to adapt, and Fraunhofer IPK is supporting them along the way.

Reducing energy consumption, reusing materials, reducing greenhouse gases (GHG): If we want to protect nature and slow down climate change, industry will have to undergo massive changes. Measures at the corporate management level are just as important as making adjustments to the life cycles of products or to production processes – on an international level. Fraunhofer IPK offers targeted support in all these areas.

Systematically achieving sustainability

»We find that sustainability poses major challenges for SMEs in particular,« says Felix Budde. His team develops methods and digital solutions for sustainability management. For several years now, the sustainability benchmarking they developed has specifically provided SMEs with an initial indication of their performance in terms of sustainability. Current projects such as KliMaWirtschaft (see p. 43) deepen aspects of the overarching vision. »Many companies don't even know how much greenhouse gas they emit – yet only a sound basis of data makes targeted improvements possible,« summarizes Budde.

Image

The circular economy is a way towards more sustainability: Components of a product are reused at the end of its life.

Designing future-proof products

Companies achieve the greatest impact in terms of sustainability when they start with their cornerstones: their products. Fraunhofer IPK develops methods and digital solutions to design products sustainably and circularly starting at their development. A training program for companies is currently being developed on this topic – Mastering Sustainable Engineering. Janine Mügge explains the program she designed: »In an online course paired with specialist seminars, we answer questions such as these: What does sustainability mean in the engineering context? What do we as a company have to report in future? What do employees and IT systems need to be able to do?«

Implementing circular economy

The »product« lever is also a starting point for the circular economy. Instead of disposing of products in their entirety once they reach end of life, the idea is that digital support can allow them to be refurbished or broken down into components that can be reused or recycled. Mügge's team is active in this area as well. »For the circular economy to work, companies need to collaborate much more closely than they have in the past,« she says. The Catena-X project connects companies along the automotive value chain. Until now, vehicle dismantlers hardly had any access to information about the materials used in the car. This made it difficult both to reuse components and to recycle materials. The Catena-X data ecosystem not only enables the simple exchange of information. The so-called CE assistant additionally determines the best recovery strategy for the installed parts. The Aerospace-X project is developing similar concepts for the aerospace industry.

Recovery strategies are also the focus of the project Digma-DT. Here, digital twins are used to make the carbon footprint during the recovery process transparent. The overall aim is to reduce GHG emissions. Other activities at Fraunhofer IPK that promote the circular economy are aimed at recognizing components in order to prepare them for a »second life«. Technologies for identifying used parts are being developed, based on intelligent image processing supported by artificial intelligence.

»We find that sustainability poses major challenges for SMEs in particular.«

Residue-free recycling

Fraunhofer IPK is also working on materials that can be recycled without residue so that even the recovery of components that cannot be reused becomes more sustainable. Annika Brehmer, head of the Bio- and Pharmaceutical Production Technology department, and her team are researching biopolymers. Unlike conventional »forever chemicals«, they can be biodegraded by microorganisms within a few weeks. The department produces these biopolymers by fermentation from waste materials, for example to build thumb orthoses for assembly tasks in vehicle manufacturing. When the orthoses are no longer needed, they are disposed of without harming the environment.

Bridging the planet

True sustainability can only be achieved in a global context. Fraunhofer IPK therefore works with partners around the world to make production and the associated supply chains more sustainable on an international level. The institute is particularly active in Brazil. »Projects concerning sustainability or energy transition must start from different angles: Raw materials, energy, workforce and technology. Brazil has raw materials and renewable energy, we in Germany can contribute the technology,« says Dr. David Carlos Domingos, head of the Fraunhofer IPK Project Office for Advanced Manufacturing at ITA in São José dos Campos. This is why Fraunhofer IPK has supported the Brazilian National Service for Industrial Training (SENAI) in setting up a national research network. »We need local partners for targeted research. There is a lot we can learn from them,« says Markus Will, who was crucial in driving the project forward. »Because we can only initiate innovative projects that benefit the industry if we exchange ideas internationally.«

More information

www.ipk.fraunhofer.de/sustainability-benchmarking

www.ipk.fraunhofer.de/catena-x-en

www.ipk.fraunhofer.de/aerospace-x-en

www.ipk.fraunhofer.de/digma-dt-en

www.ipk.fraunhofer.de/automaticidentification-ofoldparts

www.ipk.fraunhofer.de/biofusion40-en

www.ipk.fraunhofer.de/senai-en

Contact

Annika Brehmer
+49 30 39006-486
annika.brehmer@ipk.fraunhofer.de

Felix Budde
+49 30 39006-346
felix.budde@ipk.fraunhofer.de

Dr.-Ing. David Carlos Domingos
+49 30 39006-413
david.carlos.domingos@ipk.fraunhofer.de

Janine Mügge
+49 30 39006-299
janine.muegge@ipk.fraunhofer.de

Dr.-Ing. Markus Will
+49 30 39006-339
markus.will@ipk.fraunhofer.de

Steering Sustainably

Electric mobility plays a key role in climate protection. A lot of things need to change in manufacturing and materials for the green mobility transformation to succeed.

Mobility is transforming fundamentally. In motor vehicles, combustion is giving way to new powertrains. At the same time, small vehicles with electric motors are emerging – e-bikes, kick and e-scooters and more. This diversification is changing the entire mobility sector: Materials, production processes and supplier articles are all being adapted.

A future space for vehicle companies

ReTraNetz-BB, the »Regional Transformation Network for the Vehicle and Supplier Industry Berlin-Brandenburg«, an initiative involving industry, politics and science, aims to actively shape the process. »The German mobility industry is traditionally focused on motor vehicles. The supplier structure so far comprised a lot of mechanical manufacturing,« summarizes Nikolaos-Stefanos Koutrakis, project manager on the Fraunhofer side. As a result of the powertrain transformation, 30 percent of companies now supply electronics. »This creates challenges, but also new perspectives.« ReTraNetz-BB addresses the tasks in a living lab: Not only industry products, but also their production should become carbon-neutral and environmentally friendly. Scaling components to serve vehicles other than cars in terms of both size and performance will become more attractive for suppliers. Plus: OEMs prefer to buy pre-assembled systems, like complete powertrains consisting of a motor, power electronics and battery storage, rather than individual parts. »Therefore we want to integrate parts manufacturers to create virtual system suppliers,« says Koutrakis. Topics such as digital assistance for employees (see p. 36) and energy monitoring are also being considered. »We are strengthening Germany as a production location in the process,« says Koutrakis.

Individualized production with cold spray

Additive manufacturing is seen as an innovation driver to individualize vehicle production. Large car parts with complex geometries as well as key components for electric drives can be produced using cold spray technology – highly efficiently and without tools. Fraunhofer IPK operates a robot-guided cold spray system that can be utilized for fabricating electrically conductive copper components and permanent magnets, among other parts. This enables new designs, eliminates assembly steps and streamlines production processes.

Lightweight design meets battery performance

Electric cars still tend to weigh more than those with combustion engines – mostly because of their batteries. Materials such as carbon fiber composites (CFCs) could significantly reduce weight. »However, their low thermal conductivity makes them unsuitable for batteries,« says Aybike Yalçınyüz, a researcher in the field of joining technology. One solution is to combine them with metal. »Using laser and electron beam welding technologies, we were able to produce a multi-material from CFCs and aluminum alloys.« The result: a battery housing that is half the weight of a conventional one.

Funding notice

The ReTraNetz project is funded by the German Federal Ministry of Economic Affairs and Climate Action (BMWK).

The European Union is funding the Multhem project in the research and innovation framework program 2021 to 2027 »Horizon Europe« under funding number 101091495.

More information

www.ipk.fraunhofer.de/retranetz-en

www.ipk.fraunhofer.de/cold-spray-en

www.ipk.fraunhofer.de/multhem-en

Contact

Nikolaos-Stefanos Koutrakis
+49 30 39006-213
nikolaos-stefanos.koutrakis@ipk.fraunhofer.de

Behiye Aybike Yalçınyüz
+49 30 39006-289
behiye.aybike.yalcinyuez@ipk.fraunhofer.de

Gamechanger for Circularity and Data Economy

Prof. Thomas Knothe and Theresa Riedelsheimer lead international standardization committees on digital product passports and support associations and companies in introducing them.

What is a digital product passport and what does it offer?

Riedelsheimer From February 2027, the EU will require digital product passports (DPP) for traction, two-wheeler and industrial batteries. Passport requirements for other product categories will follow step by step. A DPP can be understood as a digital ID card that contains a chain of information documenting a product through its entire life cycle. This begins with material extraction and continues through production and use all the way to end of life.

Knothe The aim behind this is to allow us to trace environmental effects as well as social aspects in the supply chain and thus, for example, reduce environmental impact and promote reuse in the long term.

What are the main challenges?

Riedelsheimer The EU provides comprehensive regulation, but implementation is not yet detailed in many areas. Companies are faced with several questions: How should we collect the required data, how do we guarantee data security and the consistent calculation of indicators? Not to mention the global dimension – the regulation applies to all products that enter the European market, including those from non-European suppliers and OEMs. There is a great need for coordination and standardization.

Knothe All of this causes uncertainty for companies in terms of costs and operational expenses and therefore the competitiveness of their products. In addition, many companies find it difficult to take advantage of the benefits of DPPs beyond just regulatory compliance, even though some excellent examples of this already exist. For instance in the area of product traceability, where products are traced after being sold and service offerings can be created based on this.

How do you support companies?

Knothe We address three levels. Firstly, in standardization, we are pushing for a technical framework that is both practical and cost-effective. Secondly, we support associations in order to create industry-specific solutions that benefit many members equally. Thirdly, our process-oriented solutions bridge the gap between existing components in a company and complete systems that meet regulatory requirements and increase value for the company at the same time.

Riedelsheimer On a technical level, we are promoting the integration with processes and systems in the companies. Some of the data is usually already available, for example in product development. This data must be passed along the chain – key words being interoperability and cross-company data exchange. We provide support in developing the necessary IT architecture, data models and interfaces – as well as software applications. In Catena-X and Aerospace-X, we apply this to circular economy topics using batteries and other components as examples.

Image

An electric car battery moves along the production line in an automotive factory.

More information

www.ipk.fraunhofer.de/battery-pass-en
www.ipk.fraunhofer.de/catena-x-en
www.ipk.fraunhofer.de/aerospace-x-en
www.ipk.fraunhofer.de/committee-work

Contact

Prof. Dr.-Ing. Thomas Knothe | +49 30 39006-195
thomas.knothe@ipk.fraunhofer.de

Theresa Riedelsheimer | +49 30 39006-219
theresa.riedelsheimer@ipk.fraunhofer.de

Industry Plus Biology Equals Future


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For three years, the BioFusion 4.0 project investigated how production can become more sustainable, circular and resilient using biological principles.

The result is a series of approaches for the production of tomorrow which have been implemented in demonstrators, taking into account the entire life cycle of industrial products. For the early life cycle phases, they show how sustainability information can be taken into account starting with product development. The production phase is optimized ecologically and socially through bio-based materials, self-organizing multi-agent systems and ergonomics detection. Automatic image recognition supports the circular end of life of degradable products. The developed solutions are showcased here.

Image

Central demonstrator using the example of a battery control module at the Mercedes-Benz Marienfelde plant

Funding notice

This research and development project was funded by the German Federal Ministry of Education and Research (BMBF) within the Framework Concept »Research for Tomorrow's Production« and managed by the Project Management Agency Forschungszentrum Karlsruhe (PTKA-PFT).

More informationen

www.ipk.fraunhofer.de/biofusion40-en

Contact
Theresa Riedelsheimer
+49 30 39006-219
theresa.riedelsheimer@ipk.fraunhofer.de

Business models for biological transformation
How can existing business models be improved and what effects do adaptations have? Business model patterns taken from the technological sub-projects, the bioeconomy and the circular economy, form the basis of a catalog of options for optimization.

Smart recycling of valuable materials
Intelligent image recognition determines the type and quantity of disposed products. Optimal logistics and processing strategies for each product are suggested based on this, their effective implementation is supported and warnings about potential sources of danger are generated.

Engineering of biologically transformed products
Digital twins of physical products and integrated databases enable real-time life cycle assessment throughout the product life cycle. The integration of planning and real data supports monitoring environmental impacts and optimizations in product design.

Bionic integration for networked production systems
The interactive situational awareness cockpit supports the management of holistic production systems and serves as a crisis management tool. An environment analysis makes changes visible at an early stage. The situational awareness cockpit helps to identify alternatives.

Ecologically intelligent services for production
A multi-agent system for the decentralized control of production processes maps all actors (such as people and machines) as software agents. These can react dynamically to disruptions and organize production processes autonomously.

Biointelligent worker assistance systems
A vest with sensors records the posture of workers and detects forced postures at assembly workstations, for example. A comparison with ergonomically ideal standards forms the basis for the targeted optimization of working conditions.

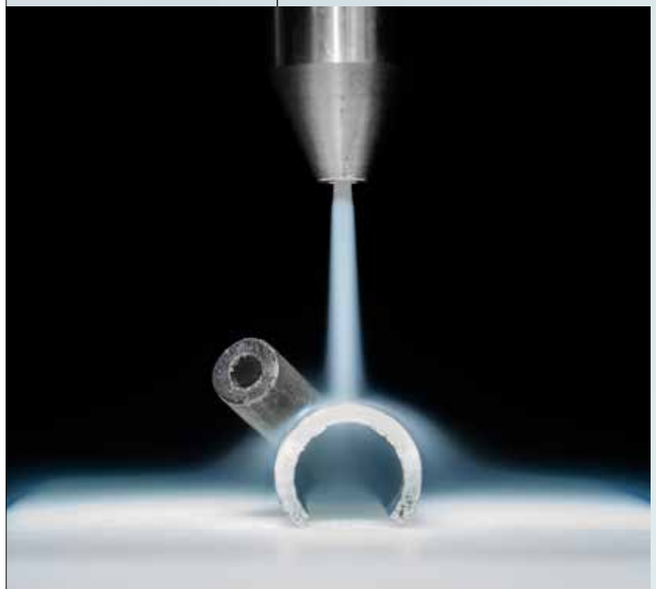
Additive manufacturing with biogenic and degradable polymers
A biodegradable plastic is produced by converting waste fats into biogenic polymers in a fermentation process that involves microorganisms. These are further processed into 3D printing granulate for the additive manufacturing of components.

01

CLEAN PRODUCTION FOR CLEAN MOBILITY

In order to achieve climate targets in the mobility sector, CO_2 emissions in road freight transport must be significantly reduced. To achieve this, the production of fuel cells must not only become more economical, but also easier to accomplish in large quantities. The H2GO – National Plan of Action for Fuel Cell Production project therefore aims to create the conditions for the economical and efficient high-volume production of fuel cells.

As part of the project, Fraunhofer IPK is developing an environmentally friendly, precise and residue-free cleaning technology for bipolar plates. This involves building an innovative cleaning cell that integrates the latest CO_2-based technologies. Using a newly developed high-pressure CO_2 jet, the bipolar plates are cleaned precisely and gently at a pressure of up to 4,000 bar without damaging the respective functional layers.
An industrial robot enables precise and automated cleaning with various CO_2 blasting processes.



Funding notice

The basis for H2GO is the »National Fuel Cell Production Action Plan«. The overall project is being funded by the German Federal Ministry for Digital and Transport with a sum of around 80 million euros from the Automotive Industry Future Fund. The funding is coordinated by NOW GmbH, and Project Management Jülich (PtJ) is responsible for implementation. The research is being conducted by 19 Fraunhofer institutes in a total of nine German states.

Contact
Philipp Burgdorf
+49 30 39006-354
philipp.burgdorf@ipk.fraunhofer.de

02

HOW SMES BENEFIT FROM RECYCLING METAL CHIPS

Many manufacturing companies are keen to contribute to the circular economy and increase their resource efficiency. SMEs in particular have often found this difficult until now. The SpanAM and FlexiMan projects therefore aim to unlock new possibilities for the use of materials in additive manufacturing through resource-saving reconditioning processes.

Both projects focus on the reconditioning of metal chips for use as raw material for laser metal deposition (LMD). Our approach enables SMEs to become more competitive by using this recycled material. The research in both projects is centered on using targeted reconditioning to turn metal chips into metal powder that can be seamlessly integrated into existing LMD processes and replace the expensive, conventional AM metal powder. We are investigating all relevant parameters to ensure a comprehensive understanding of the material properties and resulting quality of AM structures.

Funding notice

The FlexiMan project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 728053-MarTERA.

The SpanAM research project by the FOSTA – Forschungsvereinigung Stahlanwendung e. V. (Research Association for Steel Application), Düsseldorf, is supported by the German Federal Ministry for Economic Affairs and Climate Action and carried out within the framework of the program for the promotion of Industrial Collective Research (IGF) on the basis of a decision by the German Bundestag.

Contact
Vinzenz Müller
+49 30 39006-372
vinzenz.mueller@ipk.fraunhofer.de

03

THE FUTURE OF TIMBER CONSTRUCTION: DIGITALIZATION AND SUSTAINABILITY GO HAND IN HAND

The DiKieHo (Digital value chain for climate-friendly, multi-story pine-wood timber construction in the Berlin-Brandenburg region) project has set out to achieve an ambitious goal: It wants to drive forward the digitalization of multi-story timber construction in the Berlin and Brandenburg regions in order to quickly create more environmentally friendly houses. As a regional raw material, pine keeps transportation distances short, stores CO_2 and contributes to climate protection. The focus is on strengthening the digital integration of all stakeholders in the value chain »from forest to city«.

These efforts are not just about collecting and exchanging data. They involve coordinating the many stakeholders and establishing lean processes and workflows through this cooperation. This is important to ensure that houses are not only green, but also remain affordable. Intensive research is therefore also being carried out into how a balance can be struck between conserving resources and storing as much CO_2 as possible.

Partners:
- Technische Universität Berlin | Institute of Machine Tools and Factory Management (IWF) | Chair of Sustainable Corporate Development
- Technische Universität Berlin | Institute of Architecture | Sustainable Urban Planning and Urban Design | C H O R A conscious city
- Fraunhofer WKI

Contact
Nicole Oertwig
+49 30 39006-176
nicole.oertwig@
ipk.fraunhofer.de

04

MASTERING SUSTAINABILITY THROUGH PLAY: LEARNING MODULES AND SERIOUS GAMES FOR A GREEN FUTURE

The CoSuMa (Competitive Sustainable Manufacturing) project creates tailor-made learning modules that prepare teams and entire companies for making their production more sustainable and entering the circular economy. Through an engaging mix of theory and practice, participants acquire new skills and learn how sustainable decisions can strengthen the competitiveness of their company.

The training program follows a modular and blended learning approach. First, the theoretical basics are acquired via online learning platforms. Participants then apply this knowledge in complex, practical situations. In the basic module, they navigate the challenges of social responsibility, ecological consequences and corporate competitiveness in a serious game. This allows them to recognize the connection of sustainable practices and deal with the resulting conflicts of objectives and options for action. The basic module clarifies the key terms and creates a foundational understanding. The in-depth transfer modules then build on this, teaching specific expert knowledge and seamlessly transfering theory into practice.

Partners:
- Technische Universität Berlin
- German Electro and Digital Industry Association
- VDI Center for Resource Efficiency
- FAZUA GmbH
- Anton Dabatin GmbH
- Höcker Polytechnik GmbH

Contact
Natalie Petrusch
+49 30 39006-310
natalie.petrusch@
ipk.fraunhofer.de

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Funding notice
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SMART RECYCLING: USING AI AND SMARTPHONES TO RECOVER HOUSEHOLD APPLIANCES SUSTAINABLY

What happens to household appliances when they need to be disposed of? Appliances such as washing machines and fridges have to be refurbished or recycled at the end of their lifetime. The KIKERP (AI-based identification and classification of (used) electrical appliances for robotic process automation in circular economy-oriented digital management ecosystems) project aims to use smartphones to collect information about old appliances. Using AI and accessing manufacturer databases, the model and condition of an old appliance can be determined. This data is crucial for deciding whether an appliance should be refurbished or recycled.

In refurbishment, functional or easily repairable appliances are processed and put back on the market. With recycling, the appliances are broken down into their components and the raw materials are returned to the production cycle. To make the best decision between these two options, factors such as age, condition, energy efficiency and the availability of spare parts must be evaluated. This promotes a true circular economy, reduces waste and supports the sustainable use of household appliances.

Partners:
- YES Ecosystems Technology GmbH
- HaKiGo GmbH

Contact
Paul Koch
+49 30 39006-436
paul.koch@
ipk.fraunhofer.de

Fraunhofer IPK:

About Us

Fraunhofer IPK in Berlin offers system solutions with a strong digital focus for the entire spectrum of industrial tasks – from production management, product development and manufacturing to maintenance of capital goods.

Our Mission

Our goal is a sustainable production – inventive, human-centered and resource-efficient.

With the help of application-oriented research, we develop solutions along the entire industrial value circle. Our guiding idea is a digitally integrated production in which man and machine interact on the basis of data and can thus adapt flexibly and proactively to changing requirements.

Fraunhofer IPK is a research and development institution in the field of production technology. With our distinctive IT competency, we offer system solutions, individual technologies and services for digitally integrated production. We provide comprehensive support to companies from product development, planning and control of machines and systems, including technologies for parts manufacturing, to comprehensive automation and management of factory operations. We also transfer production engineering solutions to areas of application outside industry, such as traffic and safety. As an institute of the Fraunhofer-Gesellschaft, we tailor our work to fit the needs and requirements of our customers and partners. With its market orientation and high real-world value, our R&D helps to sharpen their long-term competitive edge. We develop forward-looking novel solutions and modernize, optimize and upgrade existing technologies and applications.

Fraunhofer IPK Profile

Established:
1976

Staff:
410 employees

Budget in 2023:
24.2 M €

Spin-offs:
60

Location:
Production Technology Center (PTZ) Berlin

Customers:
Industry, associations, administration, politics

International markets:
Europe, Asia, North and South America

Board of Trustees

The Board of Trustees is Fraunhofer IPK's direct line to renowned companies, associations and public institutions. The members of the board advise the institute and promote exchange with industry and funding agencies. Chairman is Dr. Ansgar Kriwet.

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Prof. Dr. Helmut Schramm	BMW Motorrad

Guaranteed Quality

In our clients' interest, we place the highest demands on the quality of our research. To guarantee this, we organize our work in standardized, structured processes that ensure a goal-oriented approach. The Deutsche Gesellschaft zur Zertifizierung von Managementsystemen (DQS) (German Association for the Certification of Management Systems) as an independent expert has certified Fraunhofer IPK according to the quality management standard DIN EN ISO 9001 since 2006.

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, based in Germany, is a leading applied research organization. It plays a crucial role in the innovation process by prioritizing research in key future technologies and transferring its research findings to industry in order to strengthen Germany as a hub of industrial activity as well as for the benefit of society. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany.

Digitally Integrated Production

We see digitally integrated production as a mission to provide companies with comprehensive support along their entire value chain. To this end, the various competencies of our research areas are perfectly intertwined.

R&D SOLUTIONS 2024 / 2025 | Expertise

More information
www.ipk.fraunhofer.de/expertise

Corporate and production management

We develop solutions for managing the sustainable and digital transformation of manufacturing companies. In addition, we help to introduce resilient and agile processes as well as to plan and realize sustainable and circular value creation systems.
Selected competencies: Process and factory management, sustainable value creation and circular economy, knowledge and competence management

Digital engineering

We realize the vision of a complete digitalization of product development and planning processes – so that you as a manufacturer or user can consider the later phases of your product's lifecycle at an early stage.
Selected competencies: Digital twins, data management and PLM, model-based systems engineering

Production processes and facilities

We optimize existing production systems, develop new machines, machining strategies as well as manufacturing technologies, including for joining and coating, and realize future-oriented tool concepts. We also offer special expertise in the field of machine and system management.
Selected competencies: Ultra- and high-precision as well as high-performance manufacturing, high-performance and precision machines as well as system management, additive manufacturing

Automation

We create new approaches for an efficient, highly flexible and safe automation of machines, systems and processes for production, as well as for logistics and circular economy processes.
Selected competencies: Machine learning for industrial processes, industrial image processing, industrial robotics

Research for Your Application

Our commercial customers include small and medium-sized enterprises in particular, as well as globally operating industrial and service companies from these five industries:

Mechanical and plant engineering
Individually customized products and their manufacturing processes are becoming the new normal in series production. With modular shop floor IT systems, IT-based automation and advanced networking of production processes and systems, we pave the way for efficient, intelligent and flexible production and support manufacturers both in their day-to-day production and in transformation processes.

Tool and mold making
Shortage of skilled workers, high energy and material costs as well as supply bottlenecks – we help this SME-dominated industry to become more digital and efficient. Our services range from the development of custom technological solutions and the planning of production facilities to the design and optimization of injection molding, machining and spark erosion processes for microfluidic, micro-optical and biomedical applications.

Automotive engineering
Electrification, digitalization and automation are the three most important accelerators of the mobility transition. On behalf of vehicle manufacturers and suppliers, we develop new technologies for diversifying drive concepts, model series and the used materials and advise on topics such as data security and data protection, user experience and connectivity services.

Aviation
Flying with low emissions, reducing fuel consumption and cutting costs – climate protection is the key driver of technological innovation in aviation. We develop additive manufacturing technologies to produce highly complex lightweight engine components, methods for 3D digitalization and inspection of service parts as well as virtual engineering environments (VR and AR) for the optimized planning of aircraft cabins.

Chemical and pharmaceutical industry
Germany's third largest industrial sector is one of the most research-intensive industries. We combine production technology and biotechnology expertise to research process chains for lab-on-chip production. Together with FDX Fluid Dynamix GmbH, we have developed FDmix, a technology platform for the rapid and robust series production of nanoparticles, which has been licensed by Lonza Group AG for GMP production.

In addition to topics from specific areas of expertise, we also drive forward interdisciplinary topics that are of particular concern to industry. These are currently for example:

Digitally integrated production (Industry 4.0)
Production is becoming networked and thus intelligent and flexible. People, workpieces and machines are linked to each other using state-of-the-art information and communication technology. As a result, all production-related information is continuously available in real time – workers, objects and systems can communicate and cooperate directly with each other.

Additive manufacturing
The potential of this manufacturing method lies in drastically shortened development times and cost-efficiently produced highly complex component geometries. While aviation and medical technology were the main drivers recently, the technology is now also being used in toolmaking, special-purpose machinery and automotive engineering.

Smart maintenance
Machines and systems are capital goods that must function reliably to ensure that their purchase is worthwhile in the long term. Smart maintenance records machine conditions in real-time, detects damage and supports maintenance with intelligent assistance.

Artificial intelligence
Human workers at the center of production are the focus point of our activities in the field of artificial intelligence. We use technologies such as neural networks as well as machine vision and learning to make production processes safer and more efficient and to provide employees in all areas of industry with the best possible support.

Digital twins
With increasing automation in production, the demand for accuracy is growing. Mistakes already made during planning and design often result in considerable additional work and higher costs. With digital twins, processes are developed and carefully tested on pilot systems. Errors are avoided and resources are saved.

We Develop Your Application

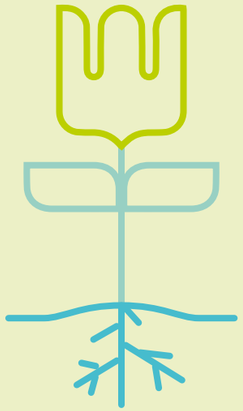
Whether globally active corporation or regional SME: Fraunhofer IPK is your research and development partner on the road to digital transformation.

Our mandate

As an institute of the Fraunhofer-Gesellschaft, we are a central link between research and practice: We transfer basic innovations from fundamental research into industrial application. Additionally, we support companies with their individual application-oriented challenges.

Our funding is made up by one third each from the following sources:

- Public base funding
- Publicly raised research funding
- Contract research earnings



Industrial application
– Companies

Application-oriented research
– Fraunhofer Institutes
– Industry-owned development centers

Basic research
– Universities
– Max Planck Institutes
– Helmholtz Centers

Here's how you can work with us

Any number of challenges your company is facing can be the starting point for a cooperation with Fraunhofer IPK: You would like more efficient processes. Your company lacks the necessary know-how or production resources to process new materials. Or maybe legal requirements demand new approaches.

Get in touch

Let us find the ideal funding structure for your development task.

Against the backdrop of such tasks, we systematically and scientifically develop holistic solutions that take into account the constraints and conditions within industry. Two forms of cooperation with industrial clients are possible here: contract research in bilateral projects and joint applications for public funding.

Contract research

- Possibility to start immediately
- Partly (co-)fundable through grants
- Individual company requirements can be addressed in a targeted approach
- Results do not have to be published

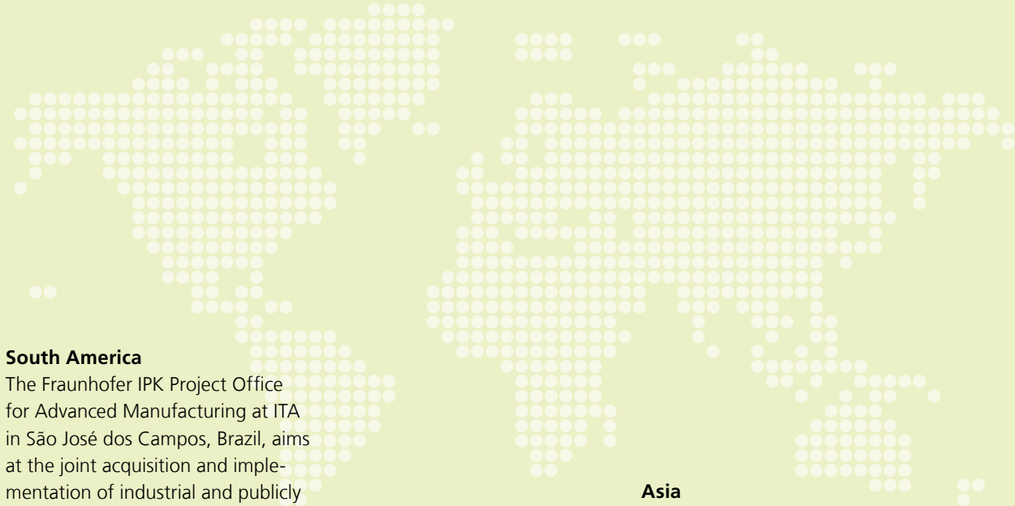
Public funding

- Funding allows a broad scope for researching potential solutions
- Numerous partners can participate in the project on an equitable basis
- Corresponding funding scheme must be available (in case of BMWK, BMBF, BMVI)
- Possible funding of 30 to 90%
- Results must be published

International Cooperation

We work with partners in numerous regions worldwide. There are clear prerequisites for our international commitment: scientific value for Fraunhofer IPK on the one hand and positive effects for both Germany and the respective partner country on the other.

Europe
EPIC is a European knowledge center for cyber-physical production systems. Its mission is to accelerate innovation, implement industrial solutions, train new generations of highly qualified professionals and support the development of a sustainable and competitive European manufacturing ecosystem.



South America
The Fraunhofer IPK Project Office for Advanced Manufacturing at ITA in São José dos Campos, Brazil, aims at the joint acquisition and implementation of industrial and publicly funded research and development projects.

Since 2012, Fraunhofer IPK has been supporting the Brazilian industry training service SENAI in setting up innovation institutes based on the Fraunhofer model.

Asia
ENRICH in China was established in October 2017 with the support of the European Commission to provide unique services to European research and technology institutions as well as companies seeking a competitive presence in the Chinese market.

More information
www.ipk.fraunhofer.de/international-en

Our Facilities

True excellence in research calls for the brightest minds and an excellent infrastructure. In order to develop solutions and products for our clients, Fraunhofer IPK is equipped with state-of-the-art development environments.

Central test area
The circular hall is where most of our experiments take place. Our high-tech test stands include numerous machine tools, assembly systems, robots, VR environments, and stand-alone devices.

Application Center for Microproduction Technology – AMP
The three AMP laboratories are equipped with state-of-the-art machines and measuring technology for high- and ultra-precision machining and process development. High-precision air conditioning technology ensures constant ambient conditions – for the most accurate results.

Industrie 4.0 Transferzentrum
In the institute's own transfer center, we show selected application-ready solutions from our applied research for industry in interactive exhibits.

1986
Production Technology Center (PTZ) Berlin inauguration

More information
www.ipk.fraunhofer.de/site

2011
AMP inauguration

10,000 sqm
Total floor space

2,350 sqm
Floor space AMP

3,200 sqm
Test area

100
Test stands

18 meters
Ceiling height in the central test area

Technology and Knowledge Transfer

Besides research and development, rapid technology transfer is the most important task for our institute. For this purpose, we offer various event formats to supplement our direct exchange with our partners in the project context. Be part of it!

With our event and professional education program MEHR KÖNNEN, we transfer technology-based know-how directly into business practice. In our certification programs, conferences, industry working groups, seminars and workshops, specialists and managers gain scientifically sound and implementation-oriented qualification in the areas of design, development, production, quality, and management. We also enable companies and organizations to use the potential of digital transformation technologies such as Artificial Intelligence, Smart Data, Internet of Things, 5G and Cloud Computing for their production and the associated business models.

In addition, with our Innovation Days we offer companies an individual format in which we present highly specialized technologies and solutions – tailored to the specific questions and needs of the respective customer. Together with you, we discuss which technologies will bring new benefits to your product portfolio, which solutions will increase the efficiency of your performance processes, and how you can overcome transformation challenges with your teams. In bilateral R&D projects, we then support and accompany you in implementing and integrating innovations in your company.

More information
www.ipk.fraunhofer.de/events

MEHR KÖNNEN

Certification Program

Mastering Digital Twins, self-paced online certification program

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»Mastering Digital Twins« is designed as an English-language online learning program. It will give you in-depth knowledge about all lifecycle phases of digital twins (idea, design, development, operation, and end of life), and a clear understanding of their business potential in different industry scenarios.

More information
www.ipk.fraunhofer.de/mastering-digital-twins-en

Inhouse Training

Business Process Optimization

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Engagement for transformation processes develops when employees can actively shape change. Our serious game »LearnFactory 5.0« is the ideal starting point for complex change processes in companies, combining emotional aspects of change with methodical and technical skills development for systematic process management.

More information
www.ipk.fraunhofer.de/business-process-optimization

Conference

DDMC2025
Fraunhofer Direct Digital Manufacturing Conference

Fraunhofer Direct Digital Manufacturing Conference DDMC

March 12–13, 2025

Organized by the Fraunhofer Competence Field Additive Manufacturing, the DDMC is a bi-annual cutting-edge forum for discussion on Additive Manufacturing, including its application in industry and the environmental impact of such new manufacturing technologies. Impact on health, sustainability and society will also be discussed.

More information
www.ddmc-fraunhofer.de

Our Experts for Your Topic

Finding answers to the challenges facing industry – Fraunhofer IPK has the right people to do just that. Contact our thought leaders directly and in person.

Institute Director
Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann
Phone +49 30 39006-100
eckart.uhlmann@ipk.fraunhofer.de

Production processes and facilities
Prof. Dr.-Ing. Julian Polte
Phone +49 30 39006-433
julian.polte@ipk.fraunhofer.de

Topics:
Industry 4.0, digitalization in production, AI in manufacturing, additive manufacturing, 3D printing, smart maintenance, condition monitoring, mechanical engineering, production systems, machine tools and system management, manufacturing processes

Ultra- and high-precision technology
Dr.-Ing. Christoph Hein
Phone +49 30 39006-405
christoph.hein@ipk.fraunhofer.de

Topics:
High- and ultra-precision and high-performance manufacturing, high-performance and precision machines and system management, additive manufacturing

Joining and coating
Prof. Dr.-Ing. Michael Rethmeier
Phone +49 30 39006-220
michael.rethmeier@ipk.fraunhofer.de

Topics:
Welding processes and technology, thick and thin sheet welding, coating processes, welding simulation, welding sequences, additive manufacturing: laser powder cladding, wire arc additive manufacturing

Corporate and production management
Prof. Dr.-Ing. Holger Kohl
Phone +49 30 39006-233
holger.kohl@ipk.fraunhofer.de

Topics:
Sustainable and digital transformation, planning of digitally integrated production systems, agile process management, resilient production, sustainable value creation systems and circular economy, benchmarking, knowledge and competence management, innovative learning formats and factories

Digital engineering
Dr.-Ing. Kai Lindow
Phone +49 30 39006-214
kai.lindow@ipk.fraunhofer.de

Topics:
Product lifecycle management, product-related sustainability, model-based systems engineering, digital product twins, intelligent data and model networking, model optimization and validation, virtual and augmented reality

Automation
Prof. Dr.-Ing. Jörg Krüger
Phone +49 30 39006-178
joerg.krueger@ipk.fraunhofer.de

Topics:
Automation, industrial robotics, human-robot collaboration, AI in automation, machine vision, optical quality control, energy efficiency optimization

Imprint

Publisher
Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann

Contact
Fraunhofer Institute for Production Systems and Design Technology IPK
Pascalstrasse 8–9
10587 Berlin
Phone +49 30 39006-140
Fax +49 30 39006-392
pr@ipk.fraunhofer.de
www.ipk.fraunhofer.de

Editorial team
Claudia Engel (responsible for content)
Katharina Strohmeier (editor-in-chief)
Dr. Janine van Ackeren
Ruth Asan
Sarah Bioly
Claudia Doyle
Jens Fischler
Benjamin Javitz
Martina Rennschmid

In case of reprinting, the editorial team's consent is required.

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Larissa Klassen (art direction)
Prerana Maheshwari, Antonia Schreiber

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Larissa Klassen
Stefanie Lehner
Andy King

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Fraunhofer Institute for Production Systems
and Design Technology IPK

Pascalstrasse 8–9 | 10587 Berlin | Phone +49 30 39006-140
pr@ipk.fraunhofer.de | www.ipk.fraunhofer.de