Manufacturing research is concerned both with fundamental and completely new technologies. It focuses on innovations which help to overcome barriers in quality and efficiency and master processes better. Here, not only the processes themselves but also the overall organization and management are taken into consideration. The spectrum ranges from strategic topics concerned with corporate development right up to technical and logistic planning processes and business operations.

Factories of the future will need to be specialized and extremely adaptable. They will be complex technical and social systems striving to operate at an optimum level of economic efficiency. Scientists will develop models, methods and technologies to facilitate superior and competitive manufacturing in all sectors of the processing industry. »High added value« is the aim of manufacturing research in Europe and Germany. Over 80 actions were recommended for acceptance in research programs on the technology platform "Manufuture". Business and research are working together to advance developments.

The location factor in manufacturing - safeguarding the future with new trends
Manufacturing is the most important sector of the German economy. It provides jobs and enables high export rates. Up-to-date manufacturing technologies also guarantee competitiveness in other branches of industry.

To keep manufacturing profitable in high-wage countries and ensure that high-quality products can still be bought at acceptable prices, companies are constantly looking for ways to optimize manufacturing conditions, independent of whether they are small, mid-sized or large-scale companies. These include the fast, flexible manufacture of individual products as well as the manufacture of products beyond regional or company boundaries.

Innovations regarding products and processes are also required in order to assert Germany’s position and include intensive research and development to enable innovative products to be launched onto the market. Processes also need to be constantly optimized in order to increase efficiency. All aspects of logistics, material flows, stock-keeping, the planning and reorganization of factory floors and production processes have to be made transparent and be optimized.

The comprehensive European technology platform “Manufuture” has pinpointed future chances and the Fraunhofer Manufacturing Alliance also presented a number of important ideas and concepts here. They are reflected in subjects such as integrative and digital manufacturing as well as in scientifically-based manufacturing and working in networks.

The piracy of products and brand names doesn’t just affect customers buying through the Internet - it has also been affecting the heavy goods industry for quite some time. New operating concepts and technologies are required to guarantee the certain identification of products and related spare parts. There are also revolutionary ideas which try to bring manufacturing closer to the customer: these include small home factories known in their country of origin, the USA, as “fabbers” or digital fabricators. The vision behind this is a 3-D printer which can be filled with metal or ceramic powder as well as numerous types of plastic in order to manufacture at the touch of a button the desired product which has been individually planned by the user. The first variations in this type of rapid manufacturing are already being utilized by industry to make spectacles and medical implants.
Adaptive manufacturing - adaptable manufacturing systems
In the future, production plants will only be successful if they are integrative and adaptive. That means adapting continuously to permanently-changing conditions – these could be alterations in piece numbers or variations in structural shape or size. Information and communication technology interfaces form the basis for this as well as innovative materials equipped with sensors and actors which send information about tool wear or whether a machine is running smoothly, for example. The model-based monitoring of complex manufacturing systems is another method which is capable of identifying optimizations in production even if manufacturing programs change rapidly. Fraunhofer researchers have developed software for doing this.

A further aspect is rapid development technologies which enable preliminary prototypes or tools to be created quickly. Rapid manufacturing is currently a big trend in this field: the technique is ideal for producing components for functional tests, unique specimens or small series. Virtual product manufacture also helps to shorten the time between the initial idea and the finished product.

Micro and nano manufacturing - handling tiny objects
Companies able to master micro-manufacturing processes have a good chance of exploiting new markets. But the requirements here are high. These include automation levels which are almost total, devices and equipment capable of adapting flexibly to the product concerned and smooth-running logistics. Often, only machines working in automated, man-free processes under cleanroom conditions are capable of working »spotlessly«.

Developers and engineers at Fraunhofer are working on various ways and means to solve micro-manufacturing problems. For example, they have created a simulation and modular device system which helps manufacturers to plan and execute production efficiently. Further aids include the modular micro fab – a miniaturized assembly unit - and special micro-manufacturing processes such as ultra-precise machining and stamping which have also been developed at Fraunhofer.

Production management - a faster way to make the perfect product
Planning and organization are indispensable to production. Decisive company advantages can be created by recognizing errors in procedures and reacting accordingly. Fraunhofer researchers have developed some new tools (e.g. digital planning table) which help to recognize weak points in existing processes or avoid them when planning new ones. Individual factory floors can be designed using simulation as can also factories and the networking of participating locations or outside companies. Quality management is and will remain a key factor in company success. With the aid of quality strategies tailored to meet specific company requirements, Fraunhofer is helping companies to achieve zero-defect production.

Comprehensive innovation management creates successful products from good ideas. Which factors impede a process, which ones speed it up? Various solution concepts can be considered using the innovation card. This creates a basis for the integrated development of products and processes and a continuous life-cycle concept.
Energy-efficient production - resource conservation as a driver of innovation

Climate protection and the shortage of raw materials make the efficient usage of existing resources an even more important subject today. Energy efficiency is also one possible answer to the question of how Germany can lastingly keep up with the constant demand for innovation and also remain competitive on the world market of the future. Energy-efficient production must be viewed integrally in the fields of new products, technologies and functional principles, innovative manufacturing equipment, new solutions for the provision of energy as well as with regard to logistics and by-processes. The manufacturing institute of the Fraunhofer-Gesellschaft has risen to the challenge in a joint initiative.

One area of application is that of engine and drive components in automobiles. The aim is to develop new products which are not only manufactured with the efficient usage of resources but which also conserve resources when in operation. In the field of applied research, we see especially the need for shorter process chains from the semi-finished to the ready-to-install product, e.g. using new process technologies for gears, by mastering new surface technologies and coatings and in developing new materials and new, integrative, flexible manufacturing equipment.

The analysis of energy efficiency in manufacturing is still incomplete. In order to determine realistic target values for future research, the Fraunhofer-Gesellschaft is currently carrying out a survey on energy efficiency in the field of manufacturing.

Service robots - inexhaustible workers

Robots are workaholics and relieve people of difficult and monotonous tasks. For safety reasons, at the moment they are still kept well-segregated from people. Fraunhofer engineers aim to unite humans and robots to form a team which works hand-in-hand. Such a close and perfectly harmonized cooperation will increase productivity and flexibility – especially as far as simple, strenuous and repetitive tasks are concerned.

Service robots are also a major growing future market beyond the field of industry. Nowadays, technical requirements can be better fulfilled than ever before: highly-efficient sensors and extremely fast data processing are accelerating advancements towards intuitive input.

Robots are also becoming more and more mobile and autonomous. This increases a willingness to give them tasks to perform not only in industry but also in the home. For example, Fraunhofer engineers are working on robots which help with home care, inspect pipelines thousands of kilometers long or investigate hazardous areas.

Manufacturing in networks - companies without boundaries

According to expert opinion, traditional series production is coming to an end. Working in collaboration with three Fraunhofer institutes, an international research team has revealed what production will look like in the future. It is developing a new concept for automobile production: the 5-day automobile. The aim is to create new standards for automobile components which are not specific to particular makes and to combine this with modular assembly. A cross-company network will enable order data and technical information to be called up where it is needed at any point in time. Requirement for this include standardized IT systems and wireless data transfer for the entire process control. New logistic solutions such as supplier parks – various suppliers located together on the same site as the works – will support effective cooperation. Warehouses and transport vehicles are used by all, saving time and money. In order to optimize processes here, Fraunhofer researchers are developing a software program which will show ideal planning and control processes. This creates many advantages, not only for the
manufacturer but also for the customer. He gets the car he wants with all the extras within the space of just one week – instead of having to wait the usual three months.

**Advance through innovation - safety and service in manufacturing**

Approximately 300 billion euros are lost worldwide every year as a result of product and brand name piracy. This doesn’t only affect brand name and mass products but increasingly also high-tech products from the field of manufacturing engineering. Fraunhofer researchers are working on a number of models and methods to stop illegal copying. These include RFID chips integrated into products which guarantee product identification as well as invisible holograms or digital watermarks.

Technical barriers can be compensated for using new operating and service models. According to Fraunhofer experts, a first and easy step in the right direction is to establish customer relationships. Another building block of the model: the efficiency of a machine becomes more important than selling it, with the result that it is leased rather than sold. All service and maintenance work is carried out by the manufacturer. The original manufacturer is also responsible for spare parts and repairs. Or manufacturers provide additional e-industrial services which make production planning, training and the servicing of the new machines easier for the customer.

**Digital production - where virtual and real worlds intermesh**

Today’s companies are set great challenges: they have to launch new products onto the market at a faster and faster rate. At the same time, customers are demanding more diverse and individual variants. This forces manufacturing companies to produce a wider range of variants and derivatives within shorter innovation and product lifecycles – a Herculean task both for design and production. Information and communication technologies come to the rescue here: the aim is to comprehensively digitize the entire process: from 3-D models, digital mock-ups and digital tests right up to virtual prototypes. The virtual and the real worlds are becoming more and more interlinked, especially as far as commissioning, service and staff training are concerned. Simulations also help to plan factories or design complex manufacturing sequences. For example, Fraunhofer supports integral planning processes by using software tools to integrate factory planning. In the product design phase, the use of virtual prototypes makes the multitude of time-consuming and cost-intensive adjustments easier and faster. Process chains can also be completely simulated. It is essential to standardize digital tools so that they can be utilized company-wide. In the project »Intelligent Manufacturing Systems«, Fraunhofer engineers have helped to create an integrated platform for a virtual reality system which supports tasks related to factory planning, process design, process monitoring and staff training.

**Hybrid value-adding - products and services in perfect harmony**

A hybrid product can be seen as being a performance bundle and represents the solution to a problem tailored to the needs of the customer. It is a combination of material goods and services which are inextricably merged. Hybrid products were initially understood as being products interlinked with services with the aim of exploiting new sales potentials and enabling closer customer relationships and orientation (Bullinger 1997). Later concepts clearly differentiate between hybrid products and new, service-orientated forms of value-adding. Thus Korell/Ganz (2000, Page 153) briefly describes two different lines in the development of hybrid products:

On the one hand, companies develop services to complement their core physical products. The products remain a key issue and the services provided are primarily seen as being product supplements.
On the other hand, manufacturing companies are further developing to become service providers as part of the orientation process towards hybrid products. In the process, the services themselves are advancing to become actual products and the original physical products lose their significance.

From hybrid products to hybrid value-adding

In the meantime, interaction in some areas between manufacturing and services has reached such a degree of integration that it makes more sense to speak of hybrid value-adding. This is not only because the character of a product is changing but also because methods of integrating products and services are providing new business models and new forms of value-adding. The »i-pod« made by Apple is an instructive example of this. The product captivates because of its aesthetic appearance and high quality but only when the »i-pod« is linked with the corresponding on-line services does it reveal its full functionality and the customer becomes aware of its added value.

The trend towards hybrid forms of value-adding is not only being observed in field of the end-user but also in inter-company business (b2c). Increasing competition, the trend towards focusing on core competencies and a more intensive distribution of work throughout the world has caused customers to demand hybrid solutions rather than individual services or Marlene! from their company partners. So-called “operating models” are a particularly well-developed form of hybrid value-adding. Operating models and “pay on production” are concepts in which the overall manufacturing process, including financing and operation of the production equipment, is conceived as being a service.

Challenges for engineering

Product design and construction are faced with new challenges as far as the development of hybrid products or hybrid forms of added value are concerned. Due to the fact that the integration of an external factor (customer) needs to be considered early on in the design process, the development of hybrid products is the next (logical) step towards customer-integrative products and integrated products and processes. These are supplemented by service engineering methods and concepts.

In order to be able to successfully plan and develop hybrid products and forms of added value, a new approach is required which permits customers or other external factors (cooperation partners, etc.) to become more closely involved in the development process. To achieve this, the Fraunhofer Institute for Industrial Engineering (IAO) has created a spatial development platform called ServLab. Based on the use of virtual reality, the platform enables products and related services to be tested and simulated with regard to their functionality, quality and aesthetic appearance already in the development phase.

Innovation cluster – united we are strong

Small and mid-sized companies do not often implement digital manufacturing. With the aid of such projects as the digital manufacturing innovation cluster in Stuttgart, for example, that should soon change. Fraunhofer institutes and the Land of Baden-Württemberg have initiated this project involving the close cooperation of the University of Stuttgart and over 20 companies from the area. The aim is to develop tools which are more efficient and user-friendly in order to make the concept of digital manufacturing more appealing to small and mid-sized companies, thus enabling them to develop new ideas into marketable products faster.
In the meantime, other innovation clusters in the field of manufacturing have come into existence in Germany as a result of such public-private partnership initiatives. These include: “mechatronic mechanical engineering” in Chemnitz, “nano for production” in Dresden, “optical technologies” in Jena, “automotive quality Saar” in Saarbrücken and “digital commercial vehicle technology” in Kaiserslautern.

Those wanting to accelerate innovation must be prepared to go beyond company and organizational limits and work with anyone and everyone capable of substantially contributing towards this goal. This means that companies and research institutes should no longer attempt to research and develop on their own but become familiar with other people’s inventions and leave novel notions which they do not want to pursue themselves to others. In short: companies and research institutes need to open themselves up to new forms of resource bundling and competence networking.

Innovations with a system

Innovation management is a core competence when it comes to increasing growth. The more innovative a company, the more profitable it will be. Excellent innovation management can increase company turnover by up to 13.5 percent. While everyone else is concentrating on reducing costs and laying off staff, successful companies are busy investing in new technologies and aiming at manufacturing high-quality products at competitive prices with good service and customer intimacy.

Despite all attempts to minimize risks through targeted, long-term innovation and technology management, innovation still poses a hazard with an unknown outcome. We must be prepared to try out new things and create a value that did not exist before.

A successful innovator requires four essential premises:

1) a clear strategy and an objective,
2) the best team available,
3) a determination to succeed and
4) a constant control loop of results.

We cannot support innovations, only the innovators themselves. These are people who do not get discouraged by set-backs. People who do not view a mistake as a disaster but rather as an opportunity to learn from, people who feed on challenge, convinced that they can even solve those problems which have not occurred yet.

Author:
Prof. Dr.-Ing. Hans-Jörg Bullinger, President of the Fraunhofer-Gesellschaft
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
Hansastraße 27 c
80686 München