A Look at Industry 4.0 – How the 4th Industrial Revolution could improve Efficiency in the Plastics Industry

Mannheim, 25.11.2015
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1. FAPS - Institute for Factory Automation and Production Systems
2. Introduction into Industry 4.0
3. The technological enablers of Industry 4.0
4. Challenges and impact on production
5. New business models
6. The future of additive manufacturing
The Institute for Factory Automation and Production Systems (FAPS) is researching the production and assembly of mechatronic products.

Institute for Factory Automation and Production Systems

- Electronics Production
- Electromechanical Engineering
- Biomechatronics
- E|Systems

Electronics Production & Electrical Engineering auf AEG Nuremberg
Research lab Automation Technical Faculty Erlangen
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The market potential for digital production technologies has a significant impact on the German economy.

Market potential for digital production technologies in Germany 2025 [in billion €]

Source: McKinsey-estimation for 2025, "Wirtschaftswoche " 12.5.2014, Nr. 20
Germany does not play a significant role in the digital economy at the present.

Revenue 2013, in billion €

<table>
<thead>
<tr>
<th>IT hardware</th>
<th>Online service providers</th>
<th>Software and IT service</th>
<th>Security software</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apple (118)</td>
<td>Google (38)</td>
<td>IBM (79)</td>
</tr>
<tr>
<td>2</td>
<td>HP (91)</td>
<td>Tencent (5)</td>
<td>Microsoft (56)</td>
</tr>
<tr>
<td>3</td>
<td>Dell (43)</td>
<td>Facebook (4)</td>
<td>Oracle (28)</td>
</tr>
<tr>
<td>4</td>
<td>Intel (40)</td>
<td>Yahoo (4)</td>
<td>SAP (16)</td>
</tr>
<tr>
<td>5</td>
<td>Cisco (35)</td>
<td>Yahoo Japan (3)</td>
<td>Tata (7)</td>
</tr>
</tbody>
</table>
Companies from the traditionally strong German machinery and plant engineering sector are increasingly acquired by international corporations.

Exemplary takeovers of German companies by foreign investors.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Acquirer</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>KION GROUP</td>
<td>Weichai Power</td>
<td>2012</td>
</tr>
<tr>
<td>MEDION</td>
<td>Lenovo</td>
<td>2011</td>
</tr>
<tr>
<td>PM</td>
<td>Sany</td>
<td>2012</td>
</tr>
<tr>
<td>SCHWING</td>
<td>XCMG</td>
<td>2012</td>
</tr>
<tr>
<td>CITIC Dicastal</td>
<td></td>
<td>2011</td>
</tr>
<tr>
<td>ThinMaterials</td>
<td>Nissan</td>
<td>2013</td>
</tr>
<tr>
<td>ZIPPEL</td>
<td>Sugino</td>
<td>2014</td>
</tr>
<tr>
<td>WALDRICH COBURG</td>
<td>Beijing No. 1 Machine Tool</td>
<td>2005</td>
</tr>
<tr>
<td>Carl Prandtl GmbH</td>
<td>Pentair</td>
<td>2012</td>
</tr>
<tr>
<td>HALLTECH</td>
<td>A&amp;A Manufacturing</td>
<td>2013</td>
</tr>
</tbody>
</table>

Sources: McKinsey, BGM Associates GmbH; Dealogic-Database
Merging the physical with the virtual world by cyber physical systems (CPS) launches the 4th industrial revolution.

Sources: DFKI, Youtube, CarDataVideo, Discovery, ZVEI
The 4th industrial revolution is technology driven and first of all based on a technical innovation.

- **Benefit**
  - Shorter cycle times
  - Flexibility

- **Technological enablers**
  - Internet of things
  - Computer
  - Assembly line / Taylor
  - Steam engine

- **Mechanization**

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**I 1.0**
Steam engine

**I 2.0**
Assembly line / Taylor

**I 3.0**
Computer

**I 4.0**
Internet of things
The enablers of Industry 4.0 only have the potential to induce an industrial revolution, if they solve the companies complexity problems.

In reference to: Yoram Koren “The Global Manufacturing Revolution”, Bauernhansl; Pictures: Telegraph.co.uk, Br.de, Audi.de, heise.de
Increasing complexity and instability are an enormous challenge along the value chain.

**Suppliers**
- Increasing complexity of the products
- Significant reduction of the product life cycles
- Possible failure of suppliers
- Insecure supply lead times

**Manufacturers**
- Short-term orders
- Increasing variety and amount of personalised products
- Small batch size
- Increasing competition about marketshare

**Customers**
- Short delivery time
- Economic growth or recession?

**Source:** Fraunhofer - Maschinenbau Riedl

Source: www.clker.com
Source: www.nbrii.com
Source: image.freepik.com
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Industry 4.0 is defined as the interaction of various technological enablers.

Ubiquitous communication

Holistic detection of environment

Cloud computing

Industry 4.0 enabler of the Internet of Things

Human-Machine-Collaboration

Mobility

Big data

Sources: Aldebaran, University of Freiburg, empa.ch, McKinsey, schaefer-tec.com, wtvox.com, Zectron
The dissolution of the classic automation pyramid towards ubiquitous communications will drastically change the industrial data processing.

**Classic automation pyramid**
- Management level
- Operations command level
- Control level
- Field level

**Conventional automation**
- Direct interconnection of field devices to controllers (e.g., via fieldbus)
- Defined communication to higher levels of the automation pyramid
- Information loss due to aggregation of data
- Losses of time due to hierarchical communication

**Ubiquitous communication**
- Networking between all entities in a production environment
- Each element is available and accessible (IP v6)
- Communication of semantic content
- Establishment of interoperable communication standards (e.g., OPC-UA)

**Source:** VDI/VDE
Today, Cyber-Physical Systems can be found in various areas like manufacturing, energy, consumer products and civil infrastructure.
Multiple sensors integrated in the cyber physical systems allow for an object to know a suitable image of the environment at any time.

### Technologies

- **Affordable availability of sensor technology**
- **Integration of sensors in mobile solutions**
- **Miniaturization and functional integration of sensors**
- **High resolution by networking of sensors**

### Value

- **Realization of global condition monitoring**
- **Realization of autonomation**
- **Condition for a safe human-maschine-cooperation**
- **Machine response to environmental conditions**

Sources: Sick, Bosch, st.com, infineon.com, voelkner.de, automation24.de
Due to the growing importance of the cloud numerous software tools will be available via internet on demand.

Cloud

- Platform-independent, mobile software applications:
  - Automatic generation of NC programs
  - Fusion of planning environment, document management and knowledge platform
  - App stores for individual functional add-ons
- Scalability, depending on company size and required performance
- Innovative business models

New questions

- Security in the cloud
- Make or Buy of services, data, software, infrastructure
Using Big Data approaches semi-structured data will be analyzed and new knowledge to increase productivity will be gained.
Big Data technologies enable significant changes to medicine, manufacturing and power autonomous driving.
New forms of mobility allow re-configurability and ultraflexible flow of material with unchanged functionality.

- Rapid reconfigurability
- Flexible flow of Material
- Implementation of One-Piece-Flow
- Complete functionality of previous systems

Sources: DHL, ingenieur.de
New forms of mobility allow re-configurability and ultraflexible flow of material with unchanged functionality.
Human-robot-systems offer great potentials for the production systems of the future.

Human-robot-systems
Association of abilities of humans and robots

Sources: turmpresse.de, autozeitung.de
KUKA and Microsoft collaborate to create the next generation of robots for the factory of the future.
The KUKA KR AGILUS demonstrates its skills with the table tennis racket - a realistic vision of what robots can be capable of in the future.
NAO is one of the first humanoid robots with a unique combination of hardware and software which makes him a friendly companion.
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The manufacturing industry needs solutions for the worldwide growing challenges.

**Increase efficiency**
- Energy- and resource efficiency as significant competition factors

**Shorten time-to-market**
- Shorter cycles of innovation
- More complex products
- Bigger data volumes

**Increase flexibility**
- Mass customization
- Volatile markets
- High productivity

The changes in production are faster than ever before!

Increasing competitiveness

Sources: Siemens, asianjournal.com, entwickler.de
The entire value chain of manufacturing companies is influenced by the technological enablers of Industry 4.0

- **Organisation development**
  - Philosophy
  - Methods

- **Product development**
  - Modularisation of resource use
  - Modularisation of expected product data

- **Work preparation**
  - Information supply
  - Orderspecific information
  - Use of planning data

- **Manufacturing**
  - Reduction of information demand
  - Improvement in process quality

- **Assembly**
  - Updating and registration of the data in real time

**Source:** TUM - Institut für Werkzeugmaschinen und Betriebswissenschaften
The automation in production planning and control allows for efficient, effective, flexible and fault resistant order processing.

Order Processing

- Use / Function
- Requirements
- Product design
- Process planning and control

Automated production planning and control

Response to events in production
- Flexible adjustment of
  - Delivery date
  - Delivery quantity
  - Machines
  - Materials
  - Processes
  - Product design

Production

Production process

Support

State of the art in production
- Flexible handling
- NC-programs
- RFID technology
- Industry 4.0-“ready“
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The end-user behavior is radically changing on the basis of new business models.

From Bookstore to eBook

From Record Store to Streaming

From Yellow Pages to Marketplaces

From Taxi to Ride Sharing
„Create value, capture value“ - what is a business model and why are they important in the context of Industrie 4.0?

- Business model concepts can be used as a
  - Analysis model or a
  - Planning model.

- Study (IBM):

  Over a period of 5 years business model innovations are 6% more profitable compared to businesses with only product or process innovations.

- Industrie 4.0 relies on different enabling technologies:

  ...which are affecting current and future business models.

Sources: IBM, Aldebaran, University of Freiburg, empa.ch, McKinsey, schaefer-tec.com, wtvox.com, Zectron
Business models describe how companies do business and can be characterized by four core elements (What-Who-How-Value).

- Who are our customers?
- What are we offering to our customers?
- How are we producing?
- How do we create value?

“magic triangle,” according to Gassmann; Graphics: zbw-mediatalk
To ensure that the four core elements gear to each other, business models should be described in detail with a checklist.

<table>
<thead>
<tr>
<th>Who ?</th>
<th>Value ?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer</strong></td>
<td><strong>Profit model</strong></td>
</tr>
<tr>
<td>Target customer?</td>
<td>Revenue streams?</td>
</tr>
<tr>
<td>Which kind of relationship to customers?</td>
<td>Financial risks?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What ?</th>
<th>How ?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value proposition</strong></td>
<td><strong>Value chain</strong></td>
</tr>
<tr>
<td>Which customer problem is solved?</td>
<td>Which key resource does the value proposition need?</td>
</tr>
<tr>
<td>Which value will be generated?</td>
<td>What kind of competencies?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value ?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Profit model</strong></td>
</tr>
<tr>
<td>Revenue streams?</td>
</tr>
<tr>
<td>Financial risks?</td>
</tr>
</tbody>
</table>
Rolls Royce established the “power by the hour“ business model by restructuring three of their core elements.

**What?**

Airlines pay only for operation hours of turbines and do not have to buy them.

**How?**

Turbines remain in possession of Rolls Royce. They are responsible for maintenance and service.

**Value?**

Permanent revenue streams by billing of operating hours.

**Objective?**

Primary objective is reduction of maintenance work, realized by tracking and analyze of operating data based on Big Data.

Source: Rolls Royce
Hilti business model innovation – „our customers want to buy drill holes and no drill hammers“ (CEO Hilti)

<table>
<thead>
<tr>
<th>What?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilti offers a fleet management for construction machinery.</td>
<td>New concept of sales department. Changes in all aspects of value chain.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value?</th>
<th>Objective?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent value streams by service contracts.</td>
<td>Additional revenues by up- and cross-selling. IT processes and big data provide a basis for Hilits fleet management.</td>
</tr>
</tbody>
</table>

Source: Hilti
Daimler follows the trend and offers with car2go a mobility solution without selling a car.

<table>
<thead>
<tr>
<th>What?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>car2go sells mobility.</td>
<td>Car2go provides cars and meet all the</td>
</tr>
<tr>
<td>Customers pay-per-use</td>
<td>required responsibilites as well as the</td>
</tr>
<tr>
<td>for driving with a car.</td>
<td>IT infrastructure.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value?</th>
<th>Objective?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers have to pay</td>
<td>Attracting new potential customers,</td>
</tr>
<tr>
<td>a sign up fee, afterwards</td>
<td>create brand loyalty in future target</td>
</tr>
<tr>
<td>cash flow for every</td>
<td>group.</td>
</tr>
<tr>
<td>minute a car is used.</td>
<td></td>
</tr>
</tbody>
</table>

Source: car2go

E. Bogner | A Look at Industry 4.0
New business models are an essential part of the digital revolution and Industry 4.0.

**Degree of maturity of digital business models**

- Energy
- Production
- Mobility
- Healthcare
- Trade
- Media

**Motivation**

- Rapid spread of ICT and increasing digitalization of all products and processes leads to profound changes in the business models
- Power and disruptive strength of this innovation was only slightly visible in the beginning
- Business models of German leadindustries are already supported by internet-based services and therefore don’t get basically into doubt

**Theses and guidelines**

- The digital revolution is characterised by the consistent digitalization of all business models in order to run intelligent products in intelligent networks
- This deep-seated change should not only be considered as a threat but as a disruptive force to design digitalization

Source: Umsetzungsempfehlungen für das Zukunftsprojekt Internetbasierte Dienste für die Wirtschaft 2014
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The AM market is expected to more than double by 2017 creating significant opportunities for new services, hardware and material sales.

Primary revenue from AM products and services [in million USD]

<table>
<thead>
<tr>
<th>Year</th>
<th>Services</th>
<th>Hardware</th>
<th>Materials</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>485</td>
<td>155</td>
<td>248</td>
<td>888</td>
</tr>
<tr>
<td>2007</td>
<td>81</td>
<td>390</td>
<td>221</td>
<td>1,492</td>
</tr>
<tr>
<td>2012</td>
<td>1,201</td>
<td>423</td>
<td>531</td>
<td>2,155</td>
</tr>
<tr>
<td>2017</td>
<td>2,650</td>
<td>1,320</td>
<td>1,580</td>
<td>5,550</td>
</tr>
</tbody>
</table>

Annual growth rate 2012 - 2017
- Services: 17%
- Hardware: 22%
- Materials: 26%
- Total: 20%

Commercially established Additive Manufacturing processes have become base technologies in rapid prototyping.

<table>
<thead>
<tr>
<th>Light polymerized</th>
<th>Laminated</th>
<th>Granular</th>
<th>Extrusion</th>
<th>3D Printing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Technology</strong></td>
<td>Stereolithography, Poly-jet modeling, Digital light processing</td>
<td>Laminated object manufacturing</td>
<td>Electron beam melting, Laser sintering, Laser beam melting, Thermal transfer sintering</td>
<td>Fused deposition modelling, Multi jet modelling</td>
</tr>
<tr>
<td><strong>Application example</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source: iPRO</td>
<td>Source: Protovanzado</td>
<td>Source: BMW</td>
<td>Source: Stratasys</td>
<td>Source: Zecttron</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Plastic, Metal, Ceramic</td>
<td>Paper, Plastic, Metal, Ceramic</td>
<td>Plastic, Foundry sand, Metal, Ceramic</td>
<td>Plastic, Foundry sand, Metal, Ceramic</td>
</tr>
<tr>
<td><strong>Concept</strong></td>
<td>Upon exposure to light, the photopolymer solidifies.</td>
<td>Contoured layers of material are cut out then bonded or fused.</td>
<td>Powdered material is selectively melted or sintered.</td>
<td>Thermoplast is softened and deposited through a heated nozzle.</td>
</tr>
</tbody>
</table>

Referring to VDI 3404
AM methods have taken rapid development in the recent years and show great application potential for the industry.

Additive manufacturing is changing:

- Higher performance machines, materials and processes
- Increasing process knowledge
- Generation of highly complex structures in quantity
- New fields of application

Change of paradigm in additive manufacturing from rapid prototyping to series production.
The combination of additive manufacturing of mechatronic products with tools for digitalization leads to revolutionized products.

**Geometric objects**
- No physical requirements except for shape of object
- Example: Design Study

**Mechanical objects**
- Parts that fulfill physical requirements
- Example: Turbine blade

**Mechatronic objects**
- Parts with enhanced mechatronic functionalities
- Example: Hearing aid

Sources: Materialise, MTU, Siemens
Transition from Molded Interconnect to Mechatronic Integrated Devices is essential to implement all product requirements.

**Molded Interconnect Devices**

**Mechanical functions**
- Smart systems
  - Complex components (ASICs, ICs)
  - Software functionality

**Higher complexity**
- Additional functions
- Optical, thermal, fluidic etc.

**Electrical/electronical functions**
- Adapted substrate material
  - Multi-material design
  - Plastics, metals, ceramics

**Mechatronic Integrated Devices**

- Optical, Thermal, Electrical, Mechanical functions

**Materials**
- Hybrid
- Ceramics
- Plastics
- Metals

Sources: HARTING, Kromberg & Schubert, FAPS, 2E mechatronic, Robert Bosch
The FESTO Bionic Ants are highly complex, highly integrated subsystems that work together through networking and corresponding decentralized intelligence.
Thank you!

Prof. Dr.-Ing. Jörg Franke

Institute for Factory Automation and Production Systems

Friedrich-Alexander-Universität Erlangen-Nürnberg