ETA-Factory
The energy-efficient factory of the future

AHK-Geschäftsreiseprogramm Energy Solutions – Made in Germany

Lisbon | 04.07.2017 | Dipl.-Ing. Felix Junge

04.07.2017 | Institute for Production Management, Technology and Machine Tools | Prof. Dr.-Ing. E. Abele / Prof. Dr.-Ing. J. Metternich
Who is doing research in the ETA-Factory?
TU Darmstadt and the PTW
An Engine for Innovation

27,000 Students
303 Professors (f/m)
13 Departments
5 Areas of study
110 Majors

3,200 Students
27 Faculties
700 Employees
70 Doctorates in 2014

1,300 Listeners per Year
13 Courses/Lectures
87 Employees
50 Running Research Projects and Industrial Projects
PTW Research Groups

Production Technology

Main Fields of Application:
- Mechanical Engineering
- Automotive
- Aerospace
- Dental Technology

Production Organization

Sustainable Production

Management of Industrial Production

Center for Industrial Productivity (Process Learning Factory)
Research Groups
Production Technology

Machine Tools and Components
- Mechatronic Systems and Components
- Machine Tool Spindle Units
- Industrial Robots

Machining Technology
- Machining of Powertrain-Components
- Hard-to-Machine Materials
- High Quality Drilling, Reaming and Deburring
- High Speed Cutting

Micro Production
- Digital Dental Process for unique Products
- Additive Production
- Mikro Production
Research Groups
Production Management

Center for industrial Productivity (CiP)
- Competence Development for Continuous Improvement Processes
- Flexible Parts Production
- Lean Production and Information Technology
- Flexible Assembly and Intralogistic Systems
- Lean Quality

Management of Industrial Production
- Tool Management
- Methods against Piracy of Products
- Industry 4.0

Sustainable Production
- Energy Efficiency in Production Machines
- Energetic Cross-Linkage of Production Processes and Infrastructure
- Assessment of Energy Efficiency Measures
- Energy Management & Controlling
Energy Efficiency in Industry
Motivation

Necessity of measures to increase energy efficiency

Germany’s energy transformation

Energiewende

German plans to cut carbon emissions with renewable energy are ambitious, but they are also risky


[Ref.: The New York Times; 11/2016]

The Economist; 07/2012

[Ref.: The Economist; 07/2012]
Motivation
EU energy efficiency objectives

Energy Costs
- Significant proportion of the total costs
- Rising energy costs expected

Political Relevance
- Political climate targets
- Changes in legislation (e.g. Ecolabels)

Social Responsibility
- Contribution to environmental protection
- Internal corporate objectives

EU Primary Energy Consumption Projections

Source: European Commission
Motivation
Necessity of measures to increase energy efficiency

- Biggest consumer of energy in Germany
- Machine and automotive industry: Increasing production quantities lead to a higher energy consumption
- Energy saving potentials in the industry are significant

Source: AGEB a, Prognos/EWI/GWS 2014
Energy Saving Potentials
Yearly Running Costs and Energy Saving Potentials

Highest overall consumed energy of a machine tool in the use stage

Example of an eco-profile for a milling machine

Highest environmental impact during the use stage of a machine tool life cycle

Source: ISO/DIS 14955-1

Initial investment 198.000 €

Operating time [yrs]

Annual operating costs* 38.400 €

100%

8%

press. air

26%

electricity

8%

occupancy costs

23%

repair

30%

maintenance

5%

capital commitment

Energy costs have a significant share of the annual operating costs of a machine tool

*Not included: Personnel, tool and material costs

Source: COSTRA Study PTW

Energy costs have a significant share of the annual operating costs of a machine tool

Source: COSTRA Study PTW

Highest environmental impact during the use stage of a machine tool life cycle

Source: ISO/DIS 14955-1
Energy flows of a machine tool
Energy Consumption and heat dissipation

**Electr. Power during machining process** ($P_{eff}$)
- Material removal and plastic deformation energy in the crystal lattice:
  - $< 0.1\% - 6.5\%$
- Losses:
  - $< 99.9 - 93.5\%$

**Potentials and Challenges**
- Reducing the energy consumption
  - Dimensioning
  - Energy efficiency of components
  - Efficient usage (e.g. speed control)
- Reducing costs of waste heat
  - Heat recovery
  - Cost-effective heat dissipation

*Source: Dimitriou, 2011*
Energy Efficient Configuration of Machine Tools
General Levers

Efficient components

Energy recovery

Proper dimensioning of devices

Process optimization

Constructional Optimization

Energy on-demand control strategies
Research project Maxiem
2008 - 2012

Drive System
Cooling Lubr. High Pr.
Cooling Lubr. Purging, Shower
Cooling Lubr. Forerun, Filter
Cooling Lubr. Lifting Pump
Hydraulic
Machine chiller
Control cabinet air conditioning
24V-Supply
230V-Supply
Exhaust ventilation
Pressurized air

Total Energy Savings [kWh/year]
Payback period of a machine
Payback period of a retrofit

Assumption: 3 shift manufacturing with 6d/week and a electricity price of 10c/kWh
The Project „ETA-Fabrik“
The Challenge
Holistic increase of the Energy Efficiency

Today: Isolated optimization of different sub-systems of a factory

- Building: 25%
- Building Services: 20%
- Machine: 30%

Savings < 30%

Our vision: Holistic factory optimization including all sub-systems

Interaction of:
- Machines
- Building Services
- Buildings

Synergies by energy controlling and recovery measures

Potential ~ 40%
The ETA-Project

Volume of work: 911 Research Months
Partners: 36
Third-Party funds: ca. 1 Mio €
Own Funds: ca. 3.7 Mio €
Total Volume: ca. 15 Mio €
ETA – The energy efficient model factory
Reduction of energy in production processes

Building up an energy efficiency optimized production process with our ETA-Partners

- Original process is used for the demands on quality and functionality
- Energy efficiency research based on a realistic production chain in a innovative factory building
- Interdisciplinarity for reducing the energy demand in industrial companies
**Key Innovations in the ETA Factory**
*An Overview*

**Energy Efficiency is increased by interdisciplinarity**

<table>
<thead>
<tr>
<th>Energetic interaction</th>
<th>One material: concrete</th>
<th>Modular structure</th>
</tr>
</thead>
<tbody>
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<td>Civil Engineering</td>
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<th>Energetic combination of machines, building services &amp; building</th>
<th>Holistic energy controlling</th>
<th>Smoothing of load peaks by means of kinetic energy storage</th>
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Key Word: cross-linking

Energetic interaction of machines, building services & building
From Big Data to Smart Data

ICT cross-linkage of

- Sensors (e.g. Temp., Pressure, Power, …)
- Actuators (e.g. Pumps, Valves, Drives, …)
- PLC controls

in

- Production Machines
- Building Services Equipment
- Building

>1000 Real-Time Data Points
Energy-Monitoring-System in the ETA-Factory

“If you can’t measure it, you can’t manage it.”

- Process Control & Management Level
  - SCADA Control Center
  - Energy Management System
- Control Level
  - Building Automation
  - Machine Automation
- Field Level
  - Sensors: Temperature, Volume Flow, Pressure, ...
  - Actuators: Pumps, Valves, Contactor, Devices, ...
  - Energy Meters: Electric, Heat/Cold, Compressed Air, Gas
Energy Flow Optimization
Multivariate Optimization of the holistic energy system

Control Optimization
Generation | Transformation | Storage | Distribution | Usage

Efficient Use of Energy and Energy Recovery

Flexible Use of Energy

⇒ Minimize Energy-relevant Costs
Best Practice – Decentral waste-heat using system
**Energy-crosslinked production systems**

**Why thinking about energy connections?**

**Industrial heat demand in Germany sort by temperature level**

2007

- 69% > 250°C
- 21% 150 - 250°C
- 6% 100 - 150°C
- 4% < 100°C

**High saving potential**

- **26 %** of total final energy demand in Germany is used for process heat in the industrial sector.

- Economical/technical saving potential by using waste heat (> 140°C):
  - up to **12 %** of total final energy demand in industrial sector.

- Connection between heat sources & sinks.
Two types of waste-heat sources

**Central**
- Common in bigger companies
- Number of waste-heat sources allow an appropriate accumulation and distribution infrastructure
- Only the heat exchanger unit must be integrated in the cleaning machine

**Decentral**
- Common in SME or in cases of local proximity between heat source and sink
- Time-wise separation of waste heat sink and source by implementing a thermal storage is needed

*Closer Look*
### Example of decentral waste-heat using system

Heat pump technology to transfer temperature level

<table>
<thead>
<tr>
<th>Cleaning machine</th>
<th>Solar thermal storage</th>
<th>Heat pump</th>
<th>Solar thermal storage</th>
<th>Turning machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>• One-chamber batch</td>
<td>• Volume 500 l</td>
<td>• Water/water standard-heat pump</td>
<td>• Back-up connection to central supply</td>
<td>• Three-axis, vertical pick-up</td>
</tr>
<tr>
<td>• Internal electric heating 10 kW</td>
<td>• Integrated coil-tube heat exchanger</td>
<td>• Compressor 2 kW</td>
<td>• Stainless steel</td>
<td>• Cooling demand in operation 5 kW</td>
</tr>
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![Diagram of the system showing cleaning machine, solar thermal storage, heat pump, and turning machine connected by blue pipes.]
Power consumption savings by using waste-heat

**Thermal energy**

- Without Crosslinking
- With Crosslinking

**Test conditions**

- Standard operations of cleaning machine and machine tool
- Cooling temperature 28° C
- Heating temperature 60° C
- System-COP 1.73 (include all additional components and energy losses)
Thank you for your interest!
For further questions we are happy to be at your disposal.

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