“Application of Industry 4.0 concepts at steel production from an applied research perspective“

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Industrie 4.0 is everywhere ….
Activities in steel industry in Germany / Europe

Working Group „Industrie 4.0“ of Steelinstitute VDEh:

- founded 10‘2014
- Representatives of 8 steel producers (TKSE, SZFG, HKM, AM Ruhrort, DH, voestalpine, AM Bremen, SWT), VDEh and BFI
- Development of guidelines
- First information exchange with VDMA

ESTEP Working Group „Integrated Intelligent Manufacturing (I²M)“:

- founded 2008
- members: AM, Tata, TKSE, voestalpine, (Ilva), Primetals, Danieli, BFI, CSM, Cetic, SSSA (Uni), Uni Lulea,
- Development of an European roadmap, suggestions for priorities of European research programmes, initiation of common research projects („Flag Ship Projects“)
- Workshop in April 2012 in Maziere
What means Industry 4.0?

Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final report of the Industrie 4.0 Working Group. April 2013
What is a cyber-physical system?

„…merging of information processing with physical processes“

- Strengthened usage of IT-systems which are directly embedded in the technical process,
- Intensive integration of all physical processes among themselves by suitable information flows,
- Improved interaction of the technical process with its environment,
- Adaptation of technical process and IT-systems to changing environment by learning functions,
- („Big Data analytics“: intelligent usage of large data sets)

(based on J. Jasperneite)
Aspects of Industry 4.0

- Horizontal integration
- End-to-end engineering
- Vertical integration and networked production systems
- Human being as conductor of value chain

Source: Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final report of the Industrie 4.0 Working Group, April 2013
Big Data, the four V’s

“Big Data means the analysis of large amounts of data coming from different sources with high speed and with the aim to create economic benefit“ (BITKOM)
Fields of research I

"RAMI"

"Smart Factory\textsuperscript{KL}"

"Internet of Things"

Source: http://www.smartfactory-kl.de/

"Application of Industry 4.0 concepts at steel production from an applied research perspective"
Fields of research II

Transfer of the basic ideas and concepts into real applications in industry
Introduction to steel industry
Necessary process steps ...
... and how they look in reality...
…and their complexity

mixing  solid -> liquid -> solid

casting  continuous -> semi batch -> batch -> piece

 forging

melt -> slab -> short coil -> long coil

welding  linear, non linear

static, highly dynamic, transient

galvanising

annealing

heating

painting

cutting

melting  slow (8h) -> medium (min) -> very fast (msec)

cleaning

coiling

+ many scheduling tasks
Interpretation of “Industry 4.0” for steel industry: **Steel 4.0**
Possible cyber-physical systems in steel industry

plant component

product

production plant
Cyber-Physical Production System

Simulation, predictive mainten.

intelligent plant monitoring

smart sensor

process automation/ control

MES / dec. production planning

annealing

steel shop

Communication

Simulation, learning funct.

Big Data

Data stream

Online decisions

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Horizontal Integration in steel industry

more emphasis to the integration of systems outside steel company than inside
End-to-end engineering I

plant

product design → production planning → production engineering → production → services

digital model of the plant

digital model of the product

product
End-to-end engineering II
**Vertical integration**

- **Level 1 (Field)**
- **Level 2 (Process)**
- **Level 3 (Production)**
- **Level 4 (Company)**

**Automation pyramid**

**Internet of things**
Vertical integration and networked production

- Single plant as Cyber Physical Production System (CPPS)
- Intensive networking and communication of all plants
- „Intelligent“ product with knowledge of its own quality and production history
- De-central instead of central solutions / self-organisation
Big/Smart Data in steel industry

- **High resolution** and synchronised data
- Transition to more-dimensional data („spatial“) instead only 1D
- Integration of text data, video-/audio-streams, data with gaps (**unstructured**)
- Fast processing and „**online**“-**usage** of results
Possible scenario in steel industry: “Steel 4.0”

- Necessary pre-conditions
- Through-process automation and optimisation
- Intensive data usage / data exploitation (Big Data, Smart Data, Small Data)
- Self Organisation

Product data, process data, customer demands, order data, manufacturing specifications, production sequence, maintenance data, etc.

Supply chain: product catalogue, product data, logistic data, delivery times, etc.
Necessary pre-conditions
Identification of products

- ladle
- coil
- + temperature measurement
- billet / slab
Without a suitable material tracking of all intermediate and final products Industrie 4.0 and Big Data can not be applied efficiently in steel industry.
Smart Sensors

Source: http://www.wikid.eu/index.php/Acoustic_sensors

+ temperature measurement
Semantic modelling of process chain
Electronic manufacturing specifications

Manufacturing specification No. 4711 Rev. 7

**Strip speed for customer 1 and customer 2**

For customer 1 and customer 2 the material 0815 produced via process route P5 at the annealing line a final strip temperature of about 1234°C has to be ensured. For strips up to 0.9 mm thickness the speed is around 20 m/min, for thicker strips 15 m/min.

<table>
<thead>
<tr>
<th>Rule condition</th>
<th>Monitored process value</th>
<th>Allowed values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material=0815 &amp; P=5 &amp; customer like [customer 1 or customer 2]</td>
<td>final strip temperature</td>
<td>1220 °C … 1250 °C</td>
</tr>
<tr>
<td>Material=0815 &amp; P=5 &amp; customer like [customer 1 or customer 2] &amp; thickness between 0.00 and 0.89</td>
<td>Strip speed</td>
<td>19 m/min … 21 m/min</td>
</tr>
<tr>
<td>Material=0815 &amp; P=5 &amp; customer like [customer 1 or customer 2] &amp; thickness larger then 0.90</td>
<td>Strip speed</td>
<td>14 m/min … 16 m/min</td>
</tr>
</tbody>
</table>
Through-process automation and optimisation
Through-process temperature control
Through-process control of material properties

HSM → ROT → Selective cooling device → Coiler → Fast coil cooling system → Decoiler, pickling line → FFB, IMPOC → Strip accumul., coiler

Iterative learning control

Database
Through-process Decision Support System
Ontology based material allocation
Intensive data usage / data exploitation
(“Big Data”, “Smart Data”, “Small Data”)
Data storage / handling

- MySQL
- Oracle
- SQL
- MS_SQL
- MongoDB
- CouchDB
- NoSQL

![Diagram showing technological solution with MySQL, Oracle, SQL, MS_SQL, MongoDB, CouchDB, and NoSQL highlighted.]

- 1-D continuous: strip tension, width, speed, etc
- 2-D continuous: thickness, flatness, temperature, coating layer
- Event-based: Surface defects, Internal defects, Manual data
Data usage ("Big Data", "Smart Data", "Small Data")

Did we had such a situation in the past?

What are the root causes of the surface defect "slivers"?

How will the product quality at the end of production look like?
Large Data Sets: recognition of process situations

more dimensional fast search in large data sets
Smart Data for correlation of surface defects
Big Data by Streaming Technologies

quality prediction at position F
Self-Organisation
Decentral production planning

- The product moves self organised along the process chain
- Search for best solution by using "software agents"
- Event triggered instead of planned in advance in a centralised way
- Larger flexibility in case of short term changes
Software agents to realise a virtual market place

... one piece of product misses it's target specifications...

... uses models to predict it's future state...

... and negotiates at a virtual market place for an alternative order.
Self-organised production
Final remarks

- We are at the beginning of a long term process
- Industrial companies have understood what the benefit of Industry 4.0 could be
- It takes time to realise all necessary pre-conditions
- Just now it is necessary to develop methods and concepts to transfer the idea of Industry 4.0 to each industrial sector
- First applications were still implemented without the final solution of the Internet-of-Things technology
- Industry 4.0 is from our point of view an evolution and not a revolution
Many thanks for your attention!