Industry 4.0 for the Steel Industry - from a research point of view

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Agenda

• Short description of Swerea MEFOS
• Intro to Industry 4.0 from a research point of view
• Presentation of some Industry 4.0 / digitalization projects
Swerea MEFOS in brief

- A steel mill in pilot scale
- Independent research
- Founded 1963 in Luleå
- 90 employees
- 35 member companies
- Customers all over the world
- WEB: www.swerea.se/en/mefos

Swerea MEFOS creates, refines and disseminates research results within manufacturing engineering, metalworking and the use, recovery and recycling of metals.
Intro to Industry 4.0

• Since 2011 when German Federal Ministry of Education and Research (BMBF) stated the term "Industrie 4.0" it has been an increasing effort to promote the computerization of manufacturing. So we are in the beginning of a new era of automation and control of manufacturing processes of metals as well improvement of the personal securities by using new sensors, data transfer systems, vision systems and algorithms.

• The McKinsey Digital Compass helps to identify and prioritize optimization opportunities around eight value drivers and we will present outcome from various digital research projects in some of these drivers.
McKinsey Digital Compass
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Asset utilization – Remote monitoring and control
• DISIRE
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- DISIRE
- Resource – Real-time yield optimisation
- PI-SKALP
McKinsey Digital Compass

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Asset utilization – Remote monitoring and control
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Labor – Remote monitoring and control
  • POSTECH
Industrial data management
  • DataLake4Steel
DataLake4Steel

We are moving against a total connected world with machines and humans and that means that we must handle a huge amount of data (“big data”)

The 5 V of big data

Volume – Large volume of data demands large storage capacity.

Velocity – High speed in generation and delivery of data. (On-line acquisition)

Variety – The data is generated from a wide variety of sources.

Value – How does data generate economical value through insights or other benefits?

Veracity – Quality and trust in the generated data.
DataLake4Steel

• Normally the repository of data from several sources is collected in a data warehouse (DW), which is a system used for reporting and data analysis, and is considered a core component of business intelligence. But this type of system are not flexible enough when the data is diverse or if the amount of data is very large.

• Instead a data lake (DL) is to prefer. A data lake is a storage repository that holds a vast amount of raw data in its native format.

• The term data lake is often associated with Hadoop-oriented object storage. In such a scenario, an organization's data is first loaded into the Hadoop platform, and then business analytics and data mining tools are applied to the data where it resides on Hadoop's cluster nodes of commodity computers.
# DataLake4Steel

<table>
<thead>
<tr>
<th>DATA WAREHOUSE</th>
<th>vs.</th>
<th>DATA LAKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>structured, processed</td>
<td>DATA</td>
<td>structured / semi-structured / unstructured, raw</td>
</tr>
<tr>
<td>schema-on-write</td>
<td>PROCESSING</td>
<td>schema-on-read</td>
</tr>
<tr>
<td>expensive for large data volumes</td>
<td>STORAGE</td>
<td>designed for low-cost storage</td>
</tr>
<tr>
<td>less agile, fixed configuration</td>
<td>AGILITY</td>
<td>highly agile, configure and reconfigure as needed</td>
</tr>
<tr>
<td>mature</td>
<td>SECURITY</td>
<td>maturing</td>
</tr>
<tr>
<td>business professionals</td>
<td>USERS</td>
<td>data scientists et. al.</td>
</tr>
</tbody>
</table>

![Typical Hadoop Cluster Topology](image-url)
DataLake4Steel

- Demonstration project – DataLake4Steel
- Partners
  - Swerea IVF
  - Swerea MEFOS
  - RISE SICS North
- The aim is to make a Hadoop data lake for the steel industry with goal of
  - cost reduction
  - analyze data faster, add new sources of information and make more reliable data-driven decisions.
  - integrate machine learning /AI for autonomous decision
- We're convinced that this will be a great product!
DataLake4Steel

What industries are our sources of inspiration for using data lakes and as we can learn how to build a system?

Scania Connectivity Strategy

Reference – Seminar, Luleå - Låt AI och maskininlärning lyfta din verksamhet! – 24th April 2018
Currently 290,000 connected vehicles (65% of rolling 5 year fleet)

Driving over 55,000 laps around the world every month

Reference – Seminar, Luleå - Låt AI och maskininlärning lyfta din verksamhet! – 24th April 2018
DataLake4Steel

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“Facebook runs the world’s largest Hadoop cluster” says Jay Parikh, Vice President Infrastructure Engineering, Facebook.

Basically, Facebook runs the biggest Hadoop cluster that goes beyond 4,000 machines and storing more than hundreds of millions of gigabytes.
POSTECH

No person should be hurt or killed during working at the steel plant!

Many industries share the same safety challenges and are working hard towards a zero accidents vision. As we all know, things do not always happen according to plan and sometimes we need to make important decisions without being able to see the whole picture. But what if we can go from imagining to seeing the reality and being able to adapt to it?

We have developed a game changer for workforce safety!!!
POSTECH

- The target was to create a real-time decision support system for security and safety by adapting a positioning and decision support system for the steel industry.

- Also, simultaneously, increase the efficiency and improve the logistics of humans and equipment within the steel plant.

- The project has been carried through at Swerea MEFOS preindustrial testbeds for steel making with a complete installation and adaption, and, as a final proof of concept it will be validated at SSAB.
POSTECH
Technology: Positioning of personal and machinery with UWB and RFID

- Active tags send signal to the anchor
- Anchor is placed in several positions and numbers to cover the measuring range
- Time of signal from tag to anchor is used to calculate distance
- Correlation between receiver gives position
POSTECH

Pilot demo
Installation in Mefos furnace hall
POSTECH

Pilot demo
Installation in Mefos furnace hall
Pilot demo
Installation in Mefos furnace hall
Activities

- Using Ericsson Research latest UWB positioning technology for ultra-high positioning under harsh and dangerous environment and high electromagnetic fields
- Laser-scanning, digitalizing, creating a virtual reality.
- Creating a graphical decision based system using the digital map and positioning input.
- Location of personal, visible on a digital map under all conditions
POSTECH

Activities

• Sectioning, geo-fencing, the testbed areas with various security levels
• Adapting the positioning system to manage harsh environments, and verifying the functionality under campaigns with high electromagnetic fields.
• Investigate how this kind of system will be receipted by the staff using/wearing it. The study will be performed by LTU and the department of Human work science.
• Industrial proof of concept at SSAB, targeting an isolated installation to verify testbed validation at SSAB continuous annealing line.
Result: Real-time awareness

Visualize real-time status of people and assets in a production facility for increased safety and efficiency.

- Ability to see where all employees and contractors are in case of an emergency.
- A tool for evacuation procedures, increased control that dramatically limit the time for rescue operations.
- Support for Training of mass evacuations and other safety activities in case of emergency (fire, chemical, explosions etc).
- Contractor monitoring and work permit governance: right people at the right place with right competence.
- Monitoring of lone workers.
- Access control by integrate existing system.
POSTECH

Result: Prevent accidents by automating safety

• Automated warning/notifications of safety breaches when passing digital grids in danger zones/machines and support for auto lock outs for 0-energy procedure.
• Automated warning/notifications for proximity alert for preventing traffic accidents.
• Integration & aggregation of vital information from machines, sensors, alarms, ventilation in the site.
• Basic analytics and incident reports from storing all movements and positions in the system (for risk assessment, incident investigation).
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Result: If an accident happens..

- Ability to see were all employees and contractors are in case of an emergency.
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Pi-SKALP - Adaptable platform for process integration

- Developed an automation solution for efficient raw material and energy utilization within steel industry
- To accomplish this, we have:
  - developed optimization methods for scrap based steelmaking (process integration methods)
  - designed and implement an online tool that allows for optimization of optimal raw material and energy mix to fulfill every customer order taking into account relevant processing steps
  - Possibility to share data through database in order to understand material characterization
Pi-SKALP - Adaptable platform for process integration

Data sharing, co-operative automation
- Improved characterization of e.g. scrap
- Standardization

Internal scrap optimization
- Cost of scrap, energy utilization, production costs,
- Restrictions in chemistry, availability, charging etc.
- Material property estimation (machine learning)
- Steel analysis, product, scrap class, stored in internal DB.
- Option: share data to common data base
- Other off-line process integration models added to describe current production system

Process integration
- Analysis of whole production chain
- Focus on product quality rather than steel composition from EAF
- On-line optimization of energy utilization of production costs with various boundaries such as product properties, capacity, material availability etc.
Framework for integrated process control and in-line measurements in a walking beam furnace

Project partners
Framework for integrated process control and in-line measurements in a walking beam furnace

- Robust wireless communication
  - Multi frequency option
  - 433 MHz - 2.4 GHz
  - Wide band antenna
- Survive in high temperatures
- Measure properties
  - Temperature (<1300°C)
  - Oxygen (0-10%)
- Small form factor
Framework for integrated process control and in-line measurements in a walking beam furnace

Process Modelling and Control
- Model predictive control (MPC)
  - Multi-Input Multi-Output control systems (MIMO)
  - Black box model
- Ability for the In-line sensor to update the MPC controller
- Scenario-based MPC
Cloud architecture

- All data is stored in highly secure AWS (Amazon Web Services) data centers
- Apache Spark™
  - Fast and general engine for big data processing
  - Machine learning algorithms like linear and logistic regression, clustering K-means, etc.
- Hadoop
  - Distributed storage system that provides high-throughput access to application data.
- R
  - Programming language and software environment for statistical computing
- MPC controller
Framework for integrated process control and in-line measurements in a walking beam furnace

Local architecture
- 2 new servers installed at MEFOS facility
  - Local storage server
    - Storage of data locally
  - Connectivity server
    - Take care of all internet communications
    - Read data from local storage server
    - Send data to the Cloud
- No direct control actions by the cloud MPC controller
  - Due to safety regulations
  - Furnace operator get control recommendations from the MPC controller
Framework for integrated process control and in-line measurements in a walking beam furnace

Industrial demonstration at MEFOS pilot plant

- Walking beam furnace
  - Length 12 meter
  - Slab size 170x40x20 cm
  - Oil
  - 6 burners
  - 3 zones
  - 4h heating time
- Validate and “closing the loop”
  - Wireless sensor
  - Data streaming
  - MPC module
Conclusions

- This project have described a system for measuring and controlling a WBF using cloud computing.
- The MPC controller can potentially control the furnace by using a scenario-based MPC modelling.
- The wireless sensor can measure both temperature and oxygen.
- The cloud server and the data streaming worked both upstream and downstream.
- Although the results are promising more work is needed.
  - The MPC controller needs a larger quantity of data for improvement of the statistical controller and the predictive model.
  - The wireless sensor requires work to improve its robustness.
Future visions and aims

Short term
• Create the digital infrastructure – Connect all systems to each other
• Merge personal safety system with predictive maintenance system

Long term
• The fossil-free and autonomous steelworks that produce entirely against customer orders
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