Making Sense of Industry 4.0

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Industrial revolutions

- **1784**: first mechanical weaving loom
- **1800**: manual production
- **1870**: first conveyor belt in a slaughterhouse in Cincinnati
- **1969**: first SPS, Modicon 084
- **1970**: mechanical production
- **today**: digitalized production
- **Industry 1.0**: 1800 - 1900
- **Industry 2.0**: 1970
- **Industry 3.0**: today
- **Industry 4.0**: today

source: German Research Centre for Artificial Intelligence
Industrial revolutions

- **Industry 1.0** (1784): first mechanical weaving loom
- **Industry 2.0** (1870): first conveyor belt in a slaughterhouse in Cincinnati
- **Industry 3.0** (1969): first SPS, Modicon 084
- **Industry 4.0**

The chart illustrates the evolution of industrial production from manual to digitalized production, with each revolution increasing the degree of flexibility and complexity, productivity.

Source: German Research Centre for Artificial Intelligence
ENGEL as active participant

- 1952: First ENGEL injection molding machine launched
- 1968: First electronic control system
- 1986: First smart machine on K – modular production system with robot integration
- 1990: ENGEL tie-bar-less technology
- 2016: Presentation of inject 4.0 program at K 2016
Digitalization

2005

Or the digital illumination?

2013
The role of ENGEL

ENGEL as **user**

- transformation of machine production
  - engineer to order → configure to order
- Production of customized machines with the efficiency of mass products
- Increase competitiveness due to
  - Traceability over the complete supply chain
  - Paperless value chain
  - Higher level of automation
  - Higher productivity

ENGEL as **provider**

- Development of solutions
  - to support customers on the way to their smart factory
  - enabling new levels of flexibility
- Transformation of customer potential
  - Process stability
  - Availability
  - Productivity
Main elements of Industry 4.0
Main elements of Industry 4.0
Main elements of Industry 4.0

Vertical integration

order -> sourcing -> injection moulding machine -> sensor -> product

ERP
MES

universal data utilisation
distributed intelligence
internet of things and services

Horizontal integration
Data Flow - Today
OPC-UA - Tomorrow

MATERIAL FLOW

- DRY
- DISPENSE
- WEIGH
- CUT
- MARK
- ROBOT

FLOMO
SAFETY GUARDING
ROBOT
HOTRUNNER
TEMPERATURE CONTROL

Machine network
Euromap Initiatives

- EUROMAP 77: data exchange between injection molding machines and MES
  - Successor of EM 63
  - Prototype presented at K show
  - Market Launch: 2017
- EUROMAP 79: attachment of robots to injection molding machines
  - Successor of EM 67
  - Work in progress
smart factory ...

idea: VDI Wissensforum GmbH, VDI e.V
inject 4.0
inject 4.0

Our target:

Leverage the full potential of injection molding

- **smart machine**
  Quality and process stability through adaptive production systems

- **smart service**
  Availability and maintenance through systematic data utilization

- **smart production**
  Productivity and flexibility through linking and integrating
smart machine
Intelligent Quality solutions support the users for highest process stability

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smart machine
iQ weight control

**Customer situation**
- Raw material batch variations
- Moisture fluctuations
- Changes in ambient temperature

**This results in**
- Short shots
- Overloaded cavities
iQ weight control| injection

iQ weight control compares the actual pressure curve with a previously stored reference curve.

The deviation from the reference curve is split up into three contributions:

- Injection volume
- Change in viscosity
- Conformance of pressure profile

Each contribution forms one of the new iQ weight control process parameters.
Objective of iQ weight control

• Compensate melt amount variations in the filling phase

Deviations randomly change each cycle

• Adaptation needs to be done during injection in the same cycle

Example:

*viscosity and melt amount are larger than in reference cycle*

• *Pressure rises earlier and increases more steeply*
iQ weight control | injection

The deviation from the reference curve is split up into contributions of **melt amount** and **viscosity**.
The deviation from the reference curve is split up into contributions of **melt amount** and **viscosity** online during injection.

Thus each point on the pressure curve can be associated with the corresponding point on the reference curve.

The resulting point pairs have the **same fill state of the cavity**.
iQ weight control | injection

How does iQ weight control react?

• The injection speed profile is shifted according to the detected melt amount

• Likewise the cut-over point is adapted to the actual fill state of the cavity

• These corrections are done in the same cycle – in realtime

• Outcome: Consistent fill state at switch-over to holding pressure
Hold pressure profile is automatically adapted when the viscosity changes

- Simulated viscosity change by increasing barrel temperature
- Automatic adaptation of hold pressure profile based on viscosity change
- Cavity pressure curves return to their original state
smart machine
iQ clamp control

Customer situation
- Different users set different clamp forces
- Too little or too high clamping force

This results in
- Burrs
- Bad venting → burn marks
- Unnecessary wear and tear of the molding and machine
smart machine
iQ clamp control

The ENGEL solution

- Automatically determines the ideal clamping force based on mold breathing
- Provides and monitors process relevant information about each shot

Results

- Objective and optimal setting of a critical process parameter
- Fewer rejects and high reproducibility
- Lower wear and tear of molding and machine

Available for electric clamping units of e-mac and e-motion series
Available for duo machine series: June 2017
smart machine
iQ flow control

**Customer situation**

- Different flow rates around a mold’s cavity are necessary
- No knowledge about optimal flow rate, no process reliability
- Trial and error approach to optimize the flow rate
- High energy consumption and costs
- High mold surface temperatures require longer cooling times and therefore influence productivity
smart machine
iQ flow control

The ENGEL solution

- iQ flow control communicates via OPC-UA interface with mold temperature control unit
- The speed-controlled pump provides the system with only required water quantity
- e-flomo monitors and controls the process
- Full integration in CC300

Available for new machine orders starting in April 2017
smart machine
iQ vibration control

Customer situation
- external disturbances influence the robot movement
  - ejector movement, machine vibration, movements of auxiliaries
  - strokes on the gripper, complex EOAT on long axes

The ENGEL solution
- detection and reduction of vibrations for an optimal movement
- active compensation of external disturbances

Results
- improved positioning and repeatability
- shortest molding open times
- maximum lifetime
  *Available in standard for viper 40/60 by December 2016 and viper 20/90/120 by April 2017*
smart machine
iQ vibration control

with / without

iQ vibration control
smart service
higher availability, better maintenance
smart service
e-connect | e-connect.monitor | e-connect.24 | e-connect App

More support, improved availability

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smart service
e-connect

Customer situation

- Various communication and information channels with supplier
- High effort to collect necessary information on current service cases
- Unplanned downtimes

Preview: October 2016
Market launch: October 2017
smart service
e-connect

How does it work?
- Portal as main point of communication and information
- Overview of equipment including status, alarms and warnings
- See condition of machine components
- Details on service cases (tickets, spare parts orders, etc.)
- Check price & availability of spare parts
- Send service requests

Results
- Customer and ENGEL have the same state of knowledge
- Minimized downtimes

Preview: October 2016
Market launch: October 2017

smart service
The evolution of maintenance

Up to now
- react to problems on the machine
- set regular intervals for maintenance

From now on
- analysis of machine data
- predict condition of the machine
- plan maintenance accordingly
smart service

e-connect.monitor

Customer situation
- Unexpected downtimes
- High preventive maintenance efforts
- Stocking costs for spare parts
- Varying technician and spare parts availability and delivery times
- Time-consuming root cause analysis
smart service
e-connect.monitor

Monitor
- process-critical components
- during operation
- via collected data from additional sensors

Analyze
- secure transfer of data to ENGEL
- interpretation with ENGEL algorithms
- evaluation of condition and remaining lifetime

Act
- customer feedback via ENGEL e-connect
- maintenance recommendations
- service requests and spare part orders
e-connect.monitor
Online screw monitoring

- Evaluation of screw condition
- without machine downtime
- within a few minutes
- using latest ultrasonic technology
- ENGEL service technician equipment
- All measurement results in e-connect

Available October 2017
smart service
e-connect.24

Customer situation

- Unplanned downtime (nights, weekends)
- High travel costs for service technicians

Available for all machines down to CC100 A03
smart service
e-connect.24

How does it work?
- Fixed package price per machine
- 24/7 online support
- Fast response time if problem occurs
- Access to top ENGEL experts worldwide

Results
- Minimized downtimes
- Saving of time and money

Available for all machines down to CC100 A03
smart service

e-connect App

Up-to-date wherever you are

- Available for e-connect.24 users
- Free of charge
- Overview of equipment including status, current alarms and warnings
- Overview of production status
- Possibility to send service requests

e-connect App besides iOS and Android also available for Windows 10 October 2016
smart service
Infrastructure

**e-connect platform**
- ensuring integrity of machine data
- combining measurement results with customer data
- backend for e-connect portal
- special algorithms developed by ENGEL engineers

**Webserver**
- frontend for e-connect portal
- visualization of data and information

**Connection**
- Secure end-to-end connection
- VPN tunnel with SSL/TLS data transfer
- Authentication via public key infrastructure (PKI) certificates

**ENGEL Service Box**
- communication gateway between ENGEL data center and machines
- hardened device with integrated firewall
- runs virtualized or on dedicated hardware
- collects and aggregates data according to configuration

**e-connect client**
- access to customer portal via authentication and an encrypted connection
smart production
higher productivity, greater networking
smart production

e-factory

machine network
Thank you!