How IoT can affect Machine Tool industry?

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Introduction

- Main goal in Manufacturing $\rightarrow$ Increase the Overall Equipment Efficiency

- Reduce machinery and process set-up time.
- Increase the reliability of the process
- Increase the machine uptime
- Reduce life cycle costs
- …
Introduction

- Machine Tool as a CPS
Digital Twin

- Virtual representation of machinery/processes with interaction with the real world:
  - Model optimization \(\rightarrow\) tuning
  - Virtual Commissioning \(\rightarrow\) reduction of the overall production stage of a product
  - Process control
  - References for health monitoring \(\rightarrow\) improve the detection of anomalous performance
  - …
• Digital Twin in the market
• Machine Tool as a CPS
Digital Twin

- Machine Tool modelling
  - 3D design tools (CAD)
  - Rigid body models → Kinematics and component sizing
  - FEM analysis for structural optimization
Machining Process modelling

- Software available in the market: VERICUT, MACHPRO, etc.
  - Tool path Simulation, Cutting force prediction, Stability analysis…

Optimization

MACHPro → Feedrate scheduling
• Virtual Machine Tool
  • Integration of machine dynamics, process, control and toolpath generation
• Machine Tool as a CPS
Monitoring and data management

- Data monitoring and management architecture

![Diagram showing Monitoring and data management architecture](image)
Monitoring and data management

- Monitoring infrastructure - TEKNIKER
  - Industrial micro-PC
    - Internal machine sensor monitoring (50-100 Hz)
    - Operating conditions (OPC - 1 Hz)
    - Local processing (Fingerprint, embedded models, etc)
    - Data upload to the cloud
  - External sensors
    - Vibration analyses and others
    - Third party or ad-hoc hardware
Monitoring and data management

• Data sources

**Internal sensors**
- Ethernet
- FANUC
- SIEMENS
- HEIDENHAIN
- FAGOR

**Virtual sensors**
- Tool wear control using spindle consumption monitoring

**External sensors**
- Tool holders with axial force sensor
- Accelerometers
• Data analytics

Monitoring and data management

- Learning of the wear curves and predict tool wear
- Optimized tool usage
- Minimization of tool breakage risk
- Machining conditions adaptation according to tool wear and tool change events
- Automated tool management

[Gartner, 2012]
• Machine Tool as a CPS
• iCNC: Process optimization

Cyber Physical System

PHYSICAL

Power monitoring

Signal processing

Feedrate scheduling / Stop

VIRTUAL

Model-based power estimations

Modified NC code generation
• CPSs for chatter suppression
Cyber Physical System

• Automatic MT geometric verification procedure
  • Installation of a laser tracker in the end-effector/tool
  • Reduction of verification time of big machines → 75%
  • Minimization of uncertainty due to thermal effects
Cyber Physical Systems

- Process supervision and adaptive control system
  - Integration of process and CNC Simulation models in the monitoring equipment
  - Usage of real data to:
    - Feed the models
    - Compare with simulated references
Cyber Physical Systems

- Process supervision and adaptative control system
- Collision Avoidance System
  - Avoid machine crashes by look ahead simulation of NC code including:
  - Dynamic workpiece & fixture
  - Tool shape (including holder / adapters)
  - Realistic 3D machine model
  - Support of all operating modes: AUTO / MDI / JOG modes
  - Integration in CNCs or external hardware
Conclusions

• ICT advances enable the possibility to improve MT performance through all its lifecycle

• Simulation models getting closer to reality and with enhanced possibilities: Virtual Commissioning, health monitoring…

• Monitoring and data management: several products available but companies still reluctant to “share” data

• There are commercial partners ready to sell projects results: SAMTECH-SIEMENS, ARTIS, PREDICT, MODULE WORKS
Thank you for your attention

(twincontrol.eu/)

Grant agreement 680725
• Virtual Machine Tool
  • Integration of machine dynamics, process, control and toolpath generation
Monitoring and data management

- Data analytics

Usage and MT characterisation test reports

- Descriptive Analytics
- Predictive Analytics
- Prescriptive Analytics

Value

Difficulty

Insight

Foresight

Hindsight

September 2017 – No torque saturation

January 2018 – Torque saturation

Derived from: Gartner (December 2012)